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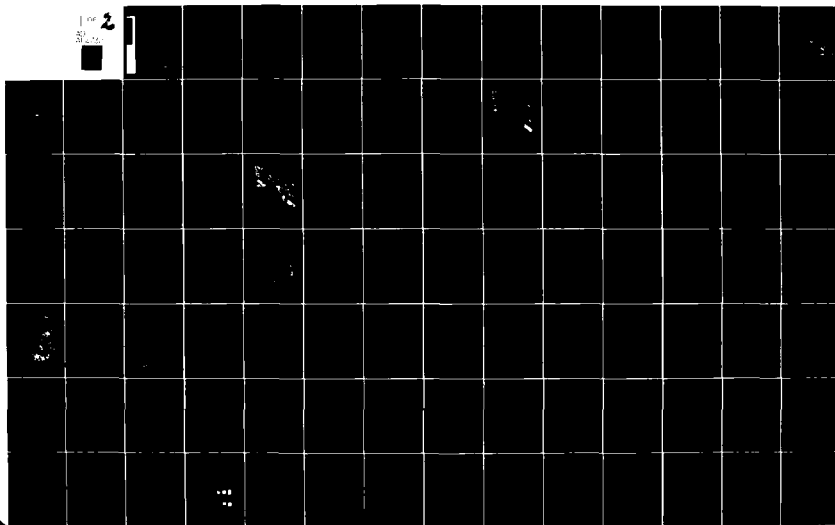
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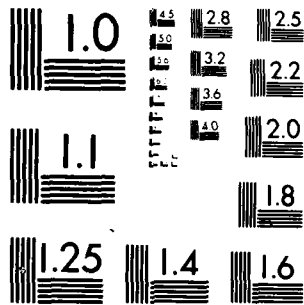
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**MX SITING INVESTIGATION
GEOTECHNICAL SUMMARY**

**PRIME CHARACTERIZATION SITES
SONORAN
CANDIDATE SITING PROVINCE**

**PREPARED FOR
SPACE AND MISSILE SYSTEMS ORGANIZATION (SAMSO)
NORTON AIR FORCE BASE, CALIFORNIA**

FURRO
NATIONAL, INC.
Consulting Engineers and Geologists

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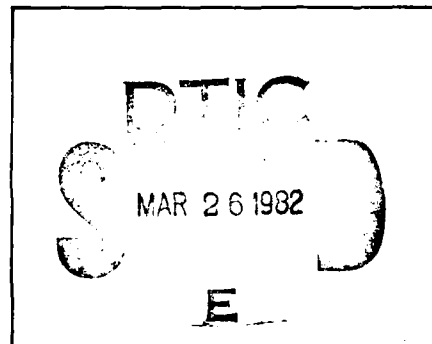
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MX SITING INVESTIGATION
GEOTECHNICAL SUMMARY
PRIME CHARACTERIZATION SITES
SONORAN
CANDIDATE SITING PROVINCE

Prepared for:

U. S. Department of the Air Force
Space and Missile Systems Organization
(SAMSO)
Norton Air Force Base, California 92409

Prepared by:

Fugro National, Inc.
3777 Long Beach Boulevard
Long Beach, California 90807

29 September 1978
15 February 1979 (rev.)

PRIME CHARACTERIZATION SITES
SONORAN CSP

ERRATA

Replace the following figures with revised ones that accompany this sheet: Figures 5 (p. 16), 6 (p. 17), 11 (p. 34), and 12 (p. 35).

Replace the following tables with revised ones that accompany this sheet: Tables 4 (p. 12), 5 (p. 19), 6 (p. 20), 12 (p. 37), and 13 (p. 38).

The following corrections are to be made to the original text:

Page i, Table of Contents, Sections 3.3, 3.3.1, 3.3.2, 3.3.3:
change page number "31" to read "30"

page ii, List of Figures, Figure 8: Change page number "28" to read "29"

page iii, List of Tables, Table 11: change page number "30" to read "31"

page 10, Figure 2: Generalized geologic map base revised, see Figure 5.

page 29: Change page number "29" to read "28".

page 29, Figure 8: Generalized geologic map base revised, see Figure 11.

page 31: Change page number "31" to read "30".

page 43, Section 4.0, line 12: Change "...through the Bouse..." to read "...through Bouse..."

FOREWORD

This report was prepared for the Department of the Air Force, Space and Missile Systems Organization (SAMSO) in compliance with conditions of Contract No. F04704-77-C-0010, and is a geotechnical summary of the two prime Characterization sites in the Sonoran Candidate Siting Province (CSP). The two sites are the Ranegras Plain, Arizona and Mojave, California.

The report presents representative data obtained from geotechnical field investigations performed at both sites as part of the Characterization program. The information obtained from these studies, in combination with data obtained in the Screening studies, has been used for geotechnical ranking (FN-TR-25).

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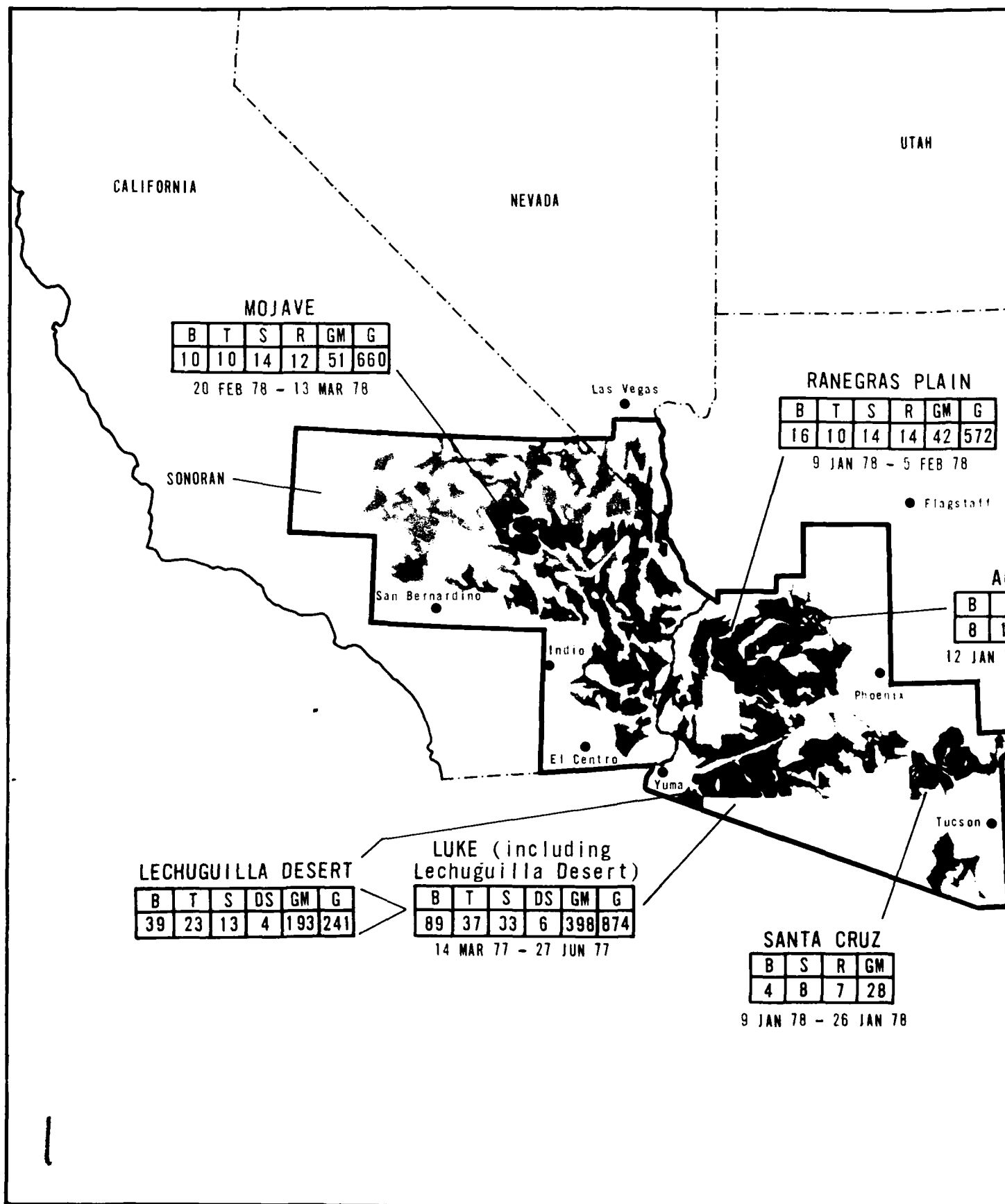
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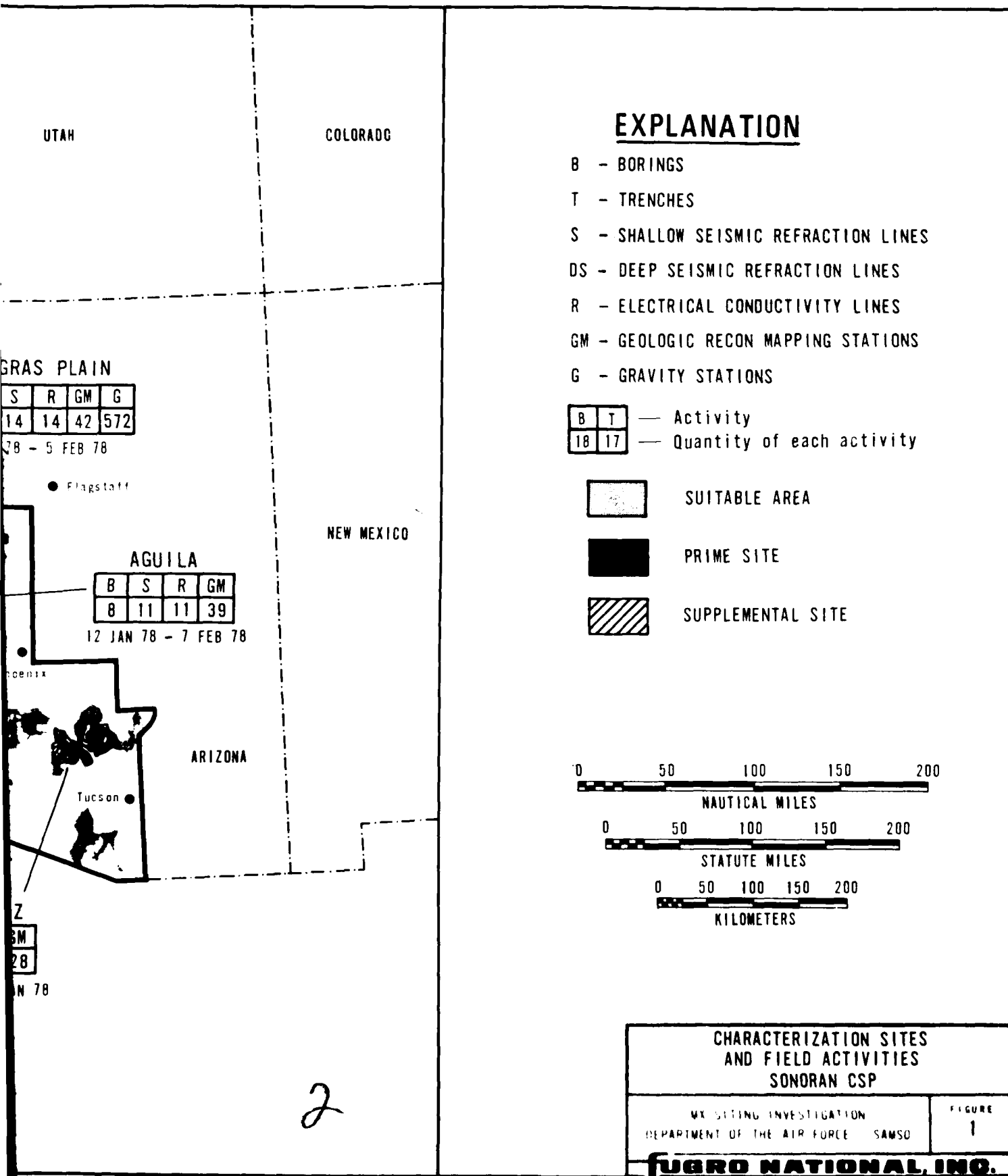
1.0 INTRODUCTION

This report presents the results of geotechnical field investigations performed in the Ranegras Plain and Mojave Characterization sites in southern Arizona and southern California, respectively. Both sites are located in the Sonoran Candidate Siting Province (CSP), one of six provinces selected in the geotechnical Characterization studies. This report presents representative data collected and analyzed for the two sites. Access to the remaining data can be arranged through SAMSO/MNND, Norton Air Force Base, California.

The Sonoran CSP is characterized by north to northwest trending elongate mountain ranges with intervening valleys. Most of the CSP lies within the states of Arizona and California, with a small portion in southern Nevada. The location of the sites within the Sonoran CSP are shown in Figure 1.

Suitable area parcels remaining after Intermediate Screening were grouped into CSPs on the basis of similar geotechnical characteristics. The results of Intermediate Screening (FN-TR-17) indicated that existing data were not adequate in type or level of detail for geotechnical and geo-environmental evaluations, screening, site selection, and ranking studies. Therefore, Characterization studies were developed to provide a rapid, relatively inexpensive method of gathering geotechnical data in a small area ($< 700 \text{ nm}^2$; 2400 km^2) which is considered to be representative of a larger area within the CSP.





Emphasis was placed on the collection of information allowing characterization of geologic units with respect to the construction aspects of MX missile basing mode options. Objectives of the Characterization studies were to obtain data that address the following geotechnical concerns:

- o Surficial geology and terrain
- o Subsurface conditions
- o Geophysical properties
- o Engineering properties

Although the program originally emphasized data collection for the trench and horizontal shelter basing modes, the data were utilized for evaluation of the vertical shelter basing mode as well. Characterization was, therefore, a refinement of the screening process whereby the necessary geotechnical information was developed to support the broader MX system design activities that were taking place concurrently and to provide a basis for geotechnical ranking of the CSPs considering alternative basing modes.

Five Characterization sites (three prime and two supplemental) were selected in the Sonoran CSP (Figure 1), representing a total investigated area of approximately 15 percent of all suitable area within the CSP. Three sites which best represent the known geologic, geomorphic, and geo-environmental setting of the largest portion of the CSP are Luke, Ranegras Plain, and Mojave. The Luke site, consisting of Lechuguilla, Mohawk-Tule, and San Cristobal valleys, was investigated and the results

were presented in our reports FN-TR-18 and 19. The Characterization site selection began with a delineation of areas within each CSP having similar depositional and geologic histories, rock and water depths, and tectonic settings. Once these areas had been identified, non-geotechnical factors were applied to delineate the actual Characterization site boundaries. These non-geotechnical selection factors included access, proximity to support facilities, environmental sensitivities, and local logistical requirements.

To determine the surface and subsurface geotechnical conditions in Ranegras Plain and Mojave sites, a combination of geologic, geophysical, and soils engineering techniques was used. These include:

- o Analysis of available data
- o Aerial photo interpretation of surficial geologic units utilizing black and white stereographic pairs at a scale of approximately 1:60,000
- o Geologic field investigation to check aerial photo interpretation and determine physical properties of the surficial units at selected field stations
- o Shallow seismic refraction and electrical conductivity surveys to obtain profile and velocity information
- o Gravity surveys for interpretation of the basin configuration
- o Drilling and trenching to determine subsurface characteristics and obtain soil samples

- o Laboratory testing of soil samples to determine their engineering properties.

The Phoenix and Riverside district offices of the U.S. Bureau of Land Management were contacted for access to the sites. Prior to initiating any field work, an archeological and environmental inspection was conducted at each site to ensure minimal impact to the local environment and to avoid damage to archeologic and historic sites. To further minimize potential impacts, all field activities were performed adjacent to existing roads or other previously disturbed areas.

2.0 RANEGRAS PLAIN SITE

The Ranegras Plain Characterization site covers an area of 578 nm² (1983 km²) in northern Yuma County, Arizona. The site consists of the Ranegras Plain and the northern part of the Harquahala Plain. The entire site is surrounded by mountains except for the southeastern corner where it is open to the southern Harquahala Plain. Arizona State Highways 60, 70, and 72 and Interstate 10 traverse the site. Numerous unpaved county roads and pipeline/transmission line service roads provide access within the site.

2.1 SCOPE OF INVESTIGATION

Scope of geologic, geophysical, and soils engineering field activities performed at the site and laboratory tests performed on soil samples from the site are presented in Table 1. Detailed information about the soils engineering field activities (16 borings and ten trenches) is summarized in Tables 2 and 3. Locations of all the field activities are shown in Figure 2.

2.2 SURFICIAL GEOLOGY AND TERRAIN

Alluvial fan deposits of younger and intermediate age are the predominant surficial geologic units in the Characterization site (Figure 2). The younger alluvial fan deposits cover approximately 55 percent of the area and the intermediate fan deposits cover 35 percent. Older alluvial fan, fluvial, and eolian deposits constitute the remaining ten percent of the site.

GEOLOGY AND GEOPHYSICS

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geological Mapping Stations	42
Shallow Refraction	14
Electrical Conductivity	14

ENGINEERING

NUMBER OF BORINGS	NOMINAL DEPTH FEET (METERS)
4	25 (8)
7	50 (15)
5	100 (30)
1	300 (91)
NUMBER OF TRENCHES	NOMINAL DEPTH FEET (METERS)
2	6 (2)
8	12 (4)

ENGINEERING-LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture/Density	186/135
Specific Gravity	6
Sieve Analysis	92
Hydrometer	80
Atterberg Limits	31
Consolidation	5

TYPE OF TEST	NUMBER OF TESTS
Unconfined Compression	17
Triaxial Compression	5
Direct Shear	42
Compaction	2
CBR	2
Chemical Analysis	5

**SCOPE OF FIELD AND LABORATORY
ACTIVITIES**

RANEGRAS PLAIN, ARIZONA, SONDRAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSCTABLE
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BORING NUMBER	TOTAL DEPTH FEET (METERS)	TYPE OF DRILL RIG USED	TYPE OF SAMPLES* OBTAINED
RP-B-3	100.8 (30.7)	Auger and Tricon	B,D,P
RP-B-4	22.0 (6.7)	Hollow Stem Auger	B,D,SS
RP-B-5	32.5 (9.9)	Hollow Stem Auger	B,D,SS
RP-B-6	302.5 (92.2)	Rotary Wash	D,B,P
RP-B-7	50.3 (15.3)	Hollow Stem Auger	B,D,SS
RP-B-8	95.0 (29.0)	Hollow Stem Auger	B,D
RP-B-9	29.5 (9.0)	Hollow Stem Auger	B,D,SS
RP-B-10	51.0 (15.5)	Hollow Stem Auger	B,D,SS
RP-B-11	40.0 (12.2)	Hollow Stem Auger	B,D,SS
RP-B-13	8.0 (2.4)	Hollow Stem Auger	B,D
RP-B-13B	62.0 (18.9)	Rotary Wash	D
RP-B-14	50.3 (15.3)	Hollow Stem Auger	B,D,SS
RP-B-15	100.0 (30.5)	Rotary Wash	B,D,P
RP-B-16	100.0 (30.5)	Rotary Wash	B,D,P
RP-B-17	50.3 (15.3)	Hollow Stem Auger	B,D
RP-B-18	81.0 (24.7)	Hollow Stem Auger	B,D,SS
RP-B-19	50.6 (15.4)	Hollow Stem Auger	B,D,SS

- * P Pitcher sample (undisturbed)
 D Fugro Drive sample (relatively undisturbed)
 B Bulk sample (disturbed)
 SS Split Spoon sample (disturbed)

ENGINEERING FIELD ACTIVITIES - BORINGS
 RANEGRAS PLAIN, ARIZONA
 SONORAN CSP

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TABLE
 2

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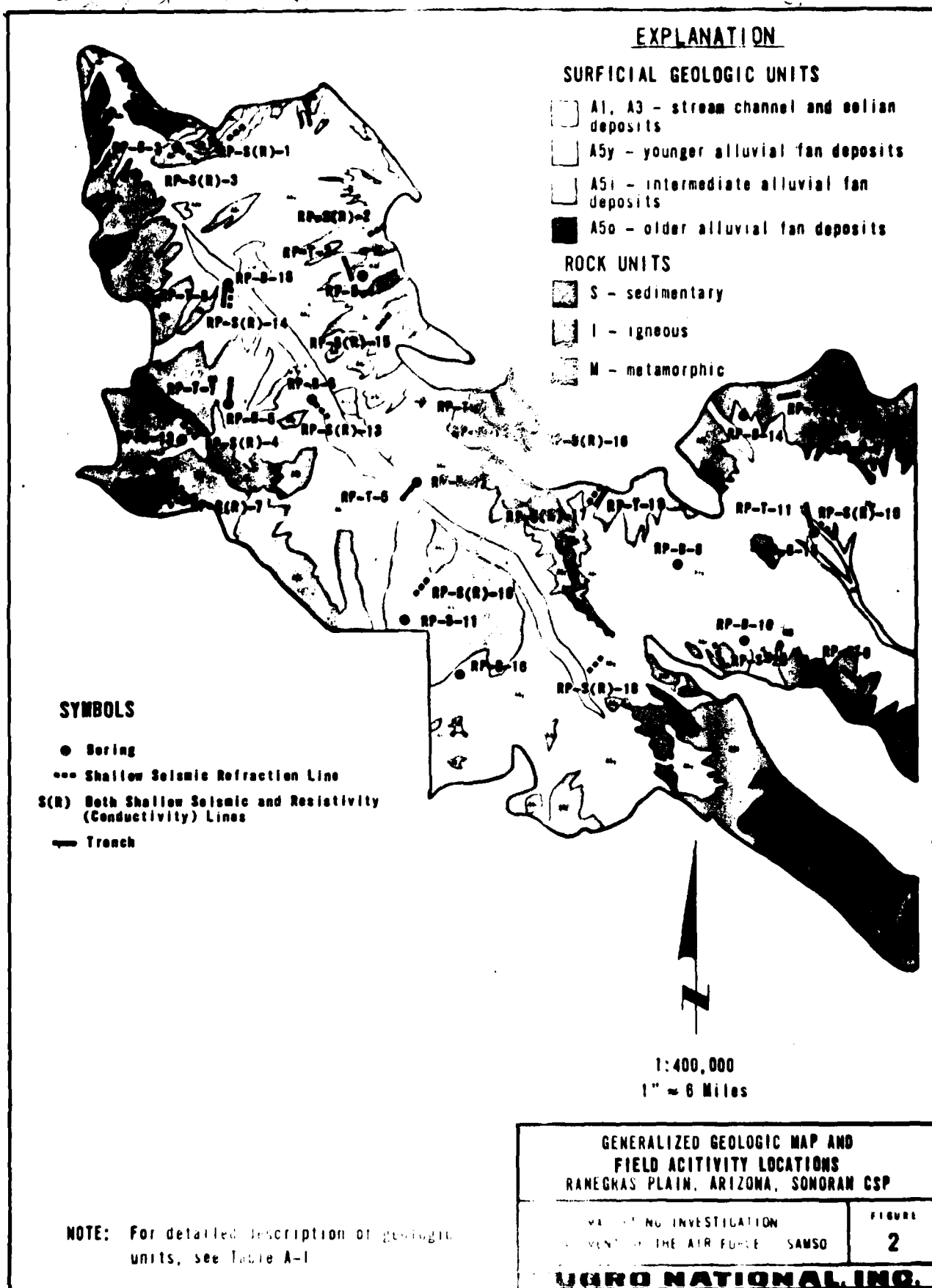
TRENCH NUMBER	TOTAL DEPTH FEET(METERS)	STABILITY OF VERTICAL EXCAVATION WALLS
RP-T-1	13.0 (4.0)	Stable
RP-T-2	12.0 (3.7)	Stable
PR-T-3	11.8 (3.6)	Stable
RP-T-4	1.9 (0.6)	Stable, backhoe refusal at 1.9' (0.6m)
PR-T-5	12.8 (3.9)	Stable
PR-T-6	11.0 (3.4)	Stable, some sloughing
RP-T-8	13.0 (4.0)	Stable
RP-T-9	11.4 (3.5)	Stable, some sloughing
RP-T-10	6.0 (1.8)	Stable
RP-T-11	11.9 (3.6)	Stable

ENGINEERING FIELD ACTIVITIES - TRENCHES
RANEGRAS PLAIN, ARIZONA
SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE
3

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Younger alluvial fan, fluvial and eolian deposits occur in the central basin area. Eolian sand deposits are concentrated east of Bouse Wash. Younger alluvial fan and fluvial deposits west of Bouse Wash are the principal source of the eolian sand deposits concentrated east of Bouse Wash. Intermediate and older alluvial fan deposits occur around the site periphery along mountain fronts. In western Ranegras Plain, however, intermediate alluvial fan deposits extend beyond this zone into the central basin.

Alluvial fan deposits predominately consist of silty sands and gravelly sands, ranging from gravelly sand near mountain fronts to sandy and clayey silts near the basin axis. Eolian deposits consist of poorly graded fine to medium-grained sands and fluvial deposits are predominately sands, and clayey silts.

Surface slopes and depths of drainage incision vary with geologic unit, both increasing with proximity to mountain fronts. Maximum surface slope is ten percent but typical slopes generally range from less than one to two percent. Maximum depths of incision (excluding older alluvial fan deposits) are ten feet (3 m) with typical depths of less than three feet (1 m). A summary of soil and terrain conditions for each surficial geologic unit is shown in Table 4.

2.3 SUBSURFACE CONDITIONS

2.3.1 Soil Profiles

Silty sands and gravelly sands are the predominant soil types in Ranegras Plain. The typical distribution of these soils is

SURFICIAL GEOLOGIC UNIT (a)	GEOLOGIC AGE	THICKNESS FEET (METERS)	DESCRIPTIVE NAME(S)	USCS SYMBOL(S)	AREAL EXTENT (SITE)		
					nm ² (km ²)	PERCENT	
Fluvial Deposits (A1)	Quaternary	Unknown	Sandy, Clayey Silt	ML	28 (96)	5	M
Eolian Dune (A3d) and Sheet (A3s) Sand Deposits	Quaternary	0-10 (0-3)	Sand	SP	4 (14)	1	
Younger Alluvial Fan Deposits (A5y)	Quaternary	0-10 (0-3)	Silty Sand, Sandy Silt	SM, ML	320 (1099)	55	M
Intermediate Alluvial Fan Deposits (A5i)	Quaternary	Unknown	Silty Sand, Sandy Silt	SM, MI	201 (690)	35	M
Older Alluvial Fan Deposits (A5o)	Quaternary- Tertiary	Unknown	Sandy Silt, Silty Sand, Sandy Gravel	ML, SM, GP	25 (86)	4	M

NOTES:

- (a) For generic description of geologic units, see Table A-1.
 (b) For description of stage of caliche, see Figure A-1.

1

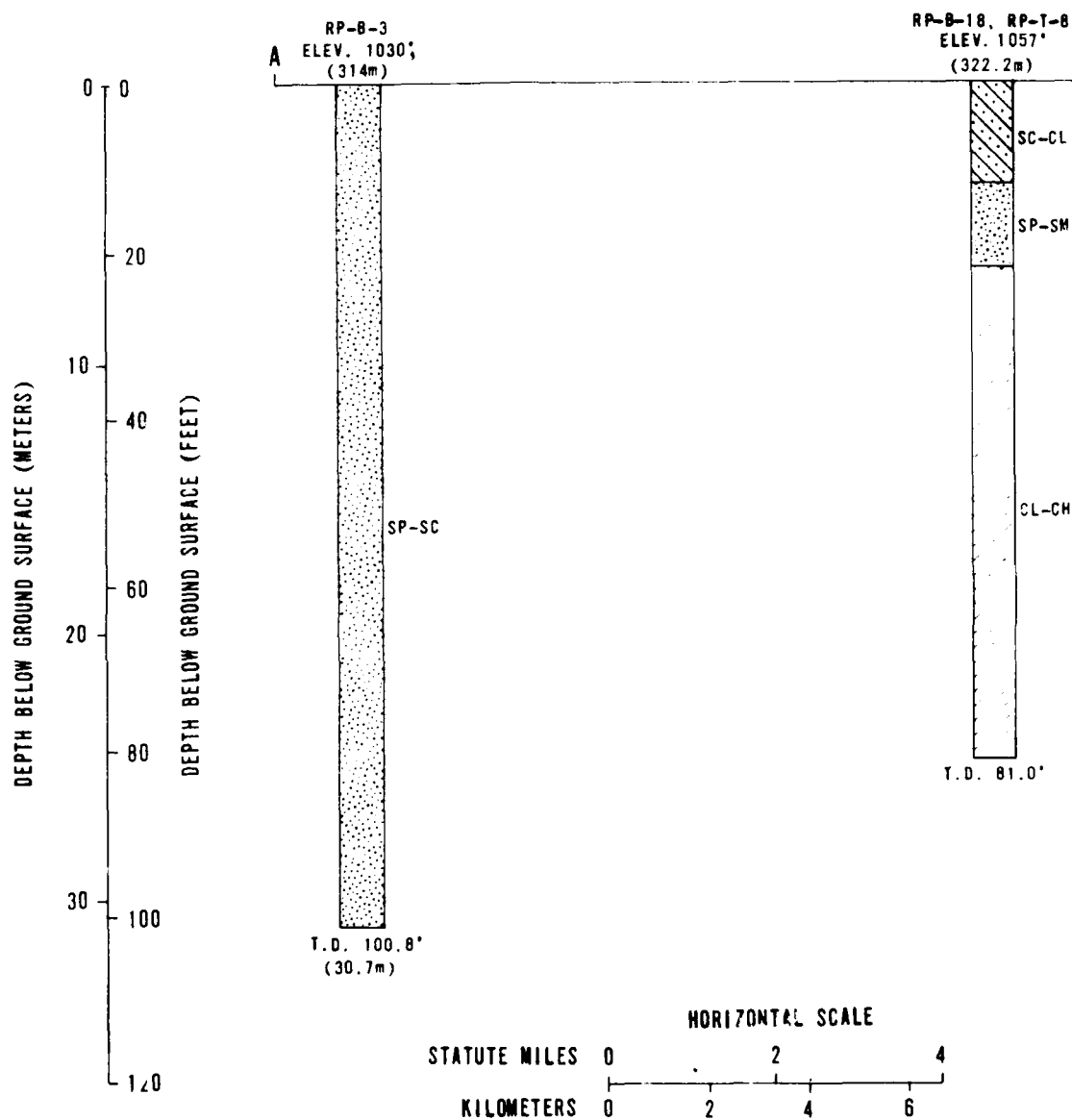
presented by two soil profiles shown in Figures 3 and 4. Percentage of fines within these sand deposits generally increases away from the mountain fronts. Cobbles and boulders are encountered only in the proximity of the mountain fronts.

2.3.2 Depth To Shallow (<150 feet; 46 m) Rock and Water

Figure 5 shows the portions of site in which rock and water are estimated to be encountered within a depth of 150 feet below ground surface. Shallow rock comprises approximately five to ten percent of the site based on interpretation from borings, seismic surveys, gravity surveys, surface outcrops, topography and geologic mapping (Figure 6). Ground water occurs at depths less than 150 feet (46 m) over approximately ten percent of the site, primarily along the northern portion of Bouse Wash. Elsewhere in the site, water is greater than 150 feet (46 m) and generally greater than 300 feet (91 m) deep.

2.3.3 Basin Configuration

The basin configuration was interpreted using gravity data (Figure 5). Cretaceous and early tertiary volcanic rocks are the predominant bedrock units defined in the gravity contour map. The average depth to bedrock is approximately 2500 feet (762 m) below the surface. Gravity interpretation suggests a collapsed caldera structure in the northwest portion of Harquahala Valley. This feature is approximately 7000 feet (2130 m) in depth and is overlain by alluvial basin-fill deposits.

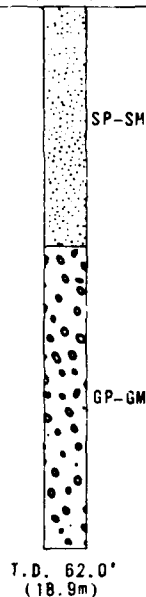
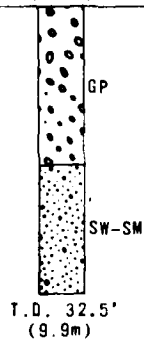


- NOTES:
1. Ground surface elevations shown at locations of borings are approximate
 2. T.D. Total Depth
 3. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix

RP-B-5, RP-T-1
ELEV. 1210'
(369m)

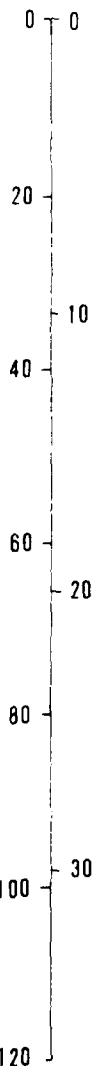
RP-B-13
ELEV. 1345'
(410m)

A

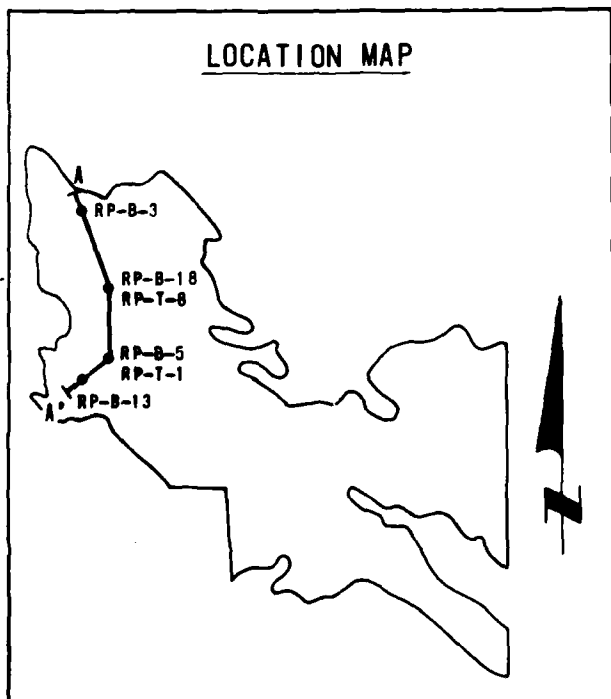


DEPTH BELOW GROUND SURFACE (FEET)

DEPTH BELOW GROUND SURFACE (METERS)



LOCATION MAP

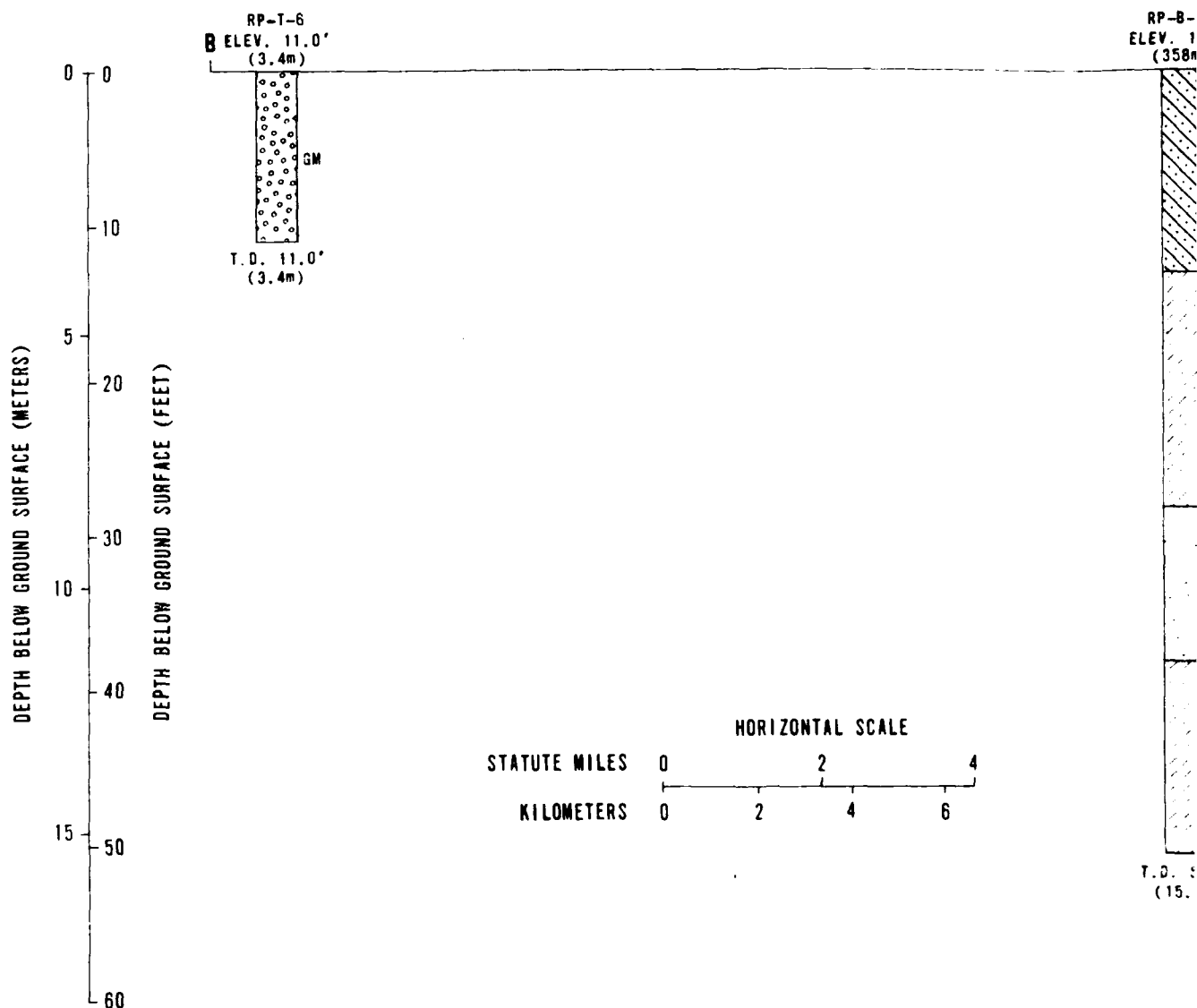


SOIL PROFILE A-A' RANEGRAS PLAIN, ARIZONA SONORAN CSP

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FIGURE
3

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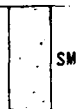
- NOTES:
1. Ground surface elevations shown at locations of borings are approximate
 2. T.D. Total Depth
 3. Soil types shown adjacent to soil column are based on Unified Soil Classification (USCS) and are explained in the appendix

RP-B-17
ELEV. 1175'
(358m)



T.D. 50.3'
(15.3m)

RP-T-10
ELEV. 1500'
(457m)



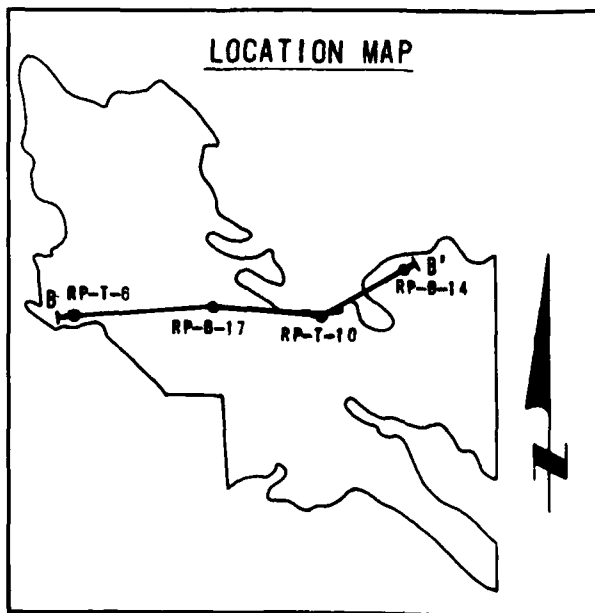
T.D. 6.0'
(1.8m)

RP-B-14
ELEV. 1820'
(494m)



T.D. 50.3'
(15.3m)

LOCATION MAP



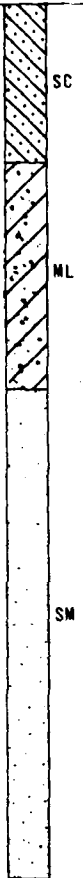
Classification System

2

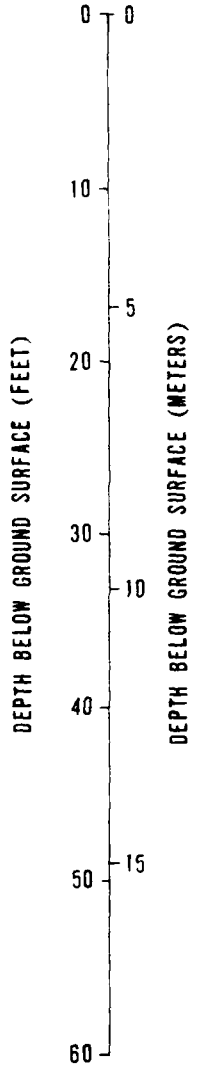
RP-T-10
ELEV. 1500'
(457m)

SM
0. 6.0'
(1.8m)

RP-B-14
ELEV. 1820'
(494m) B'



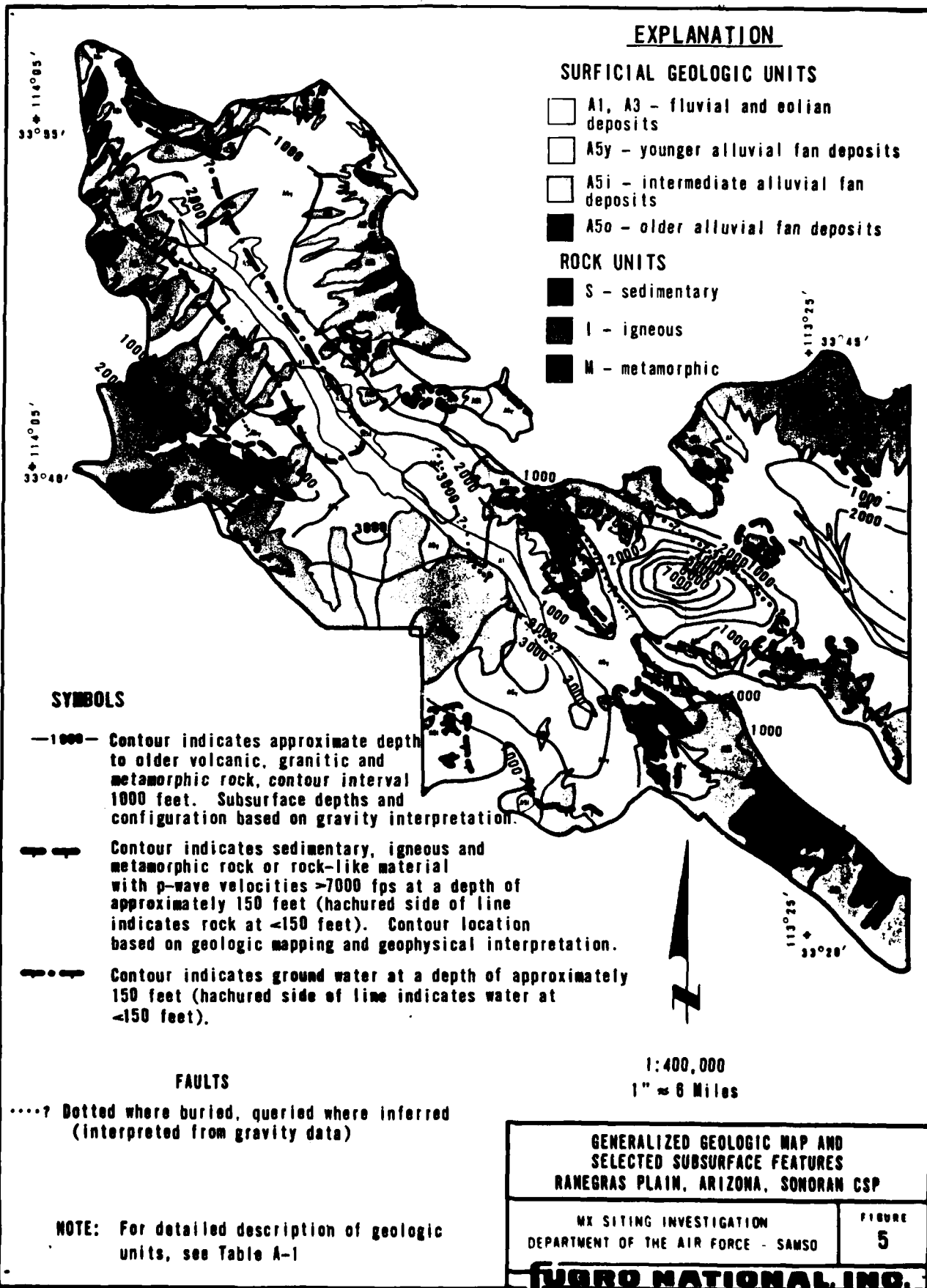
T.D. 50.3'
(15.3m)

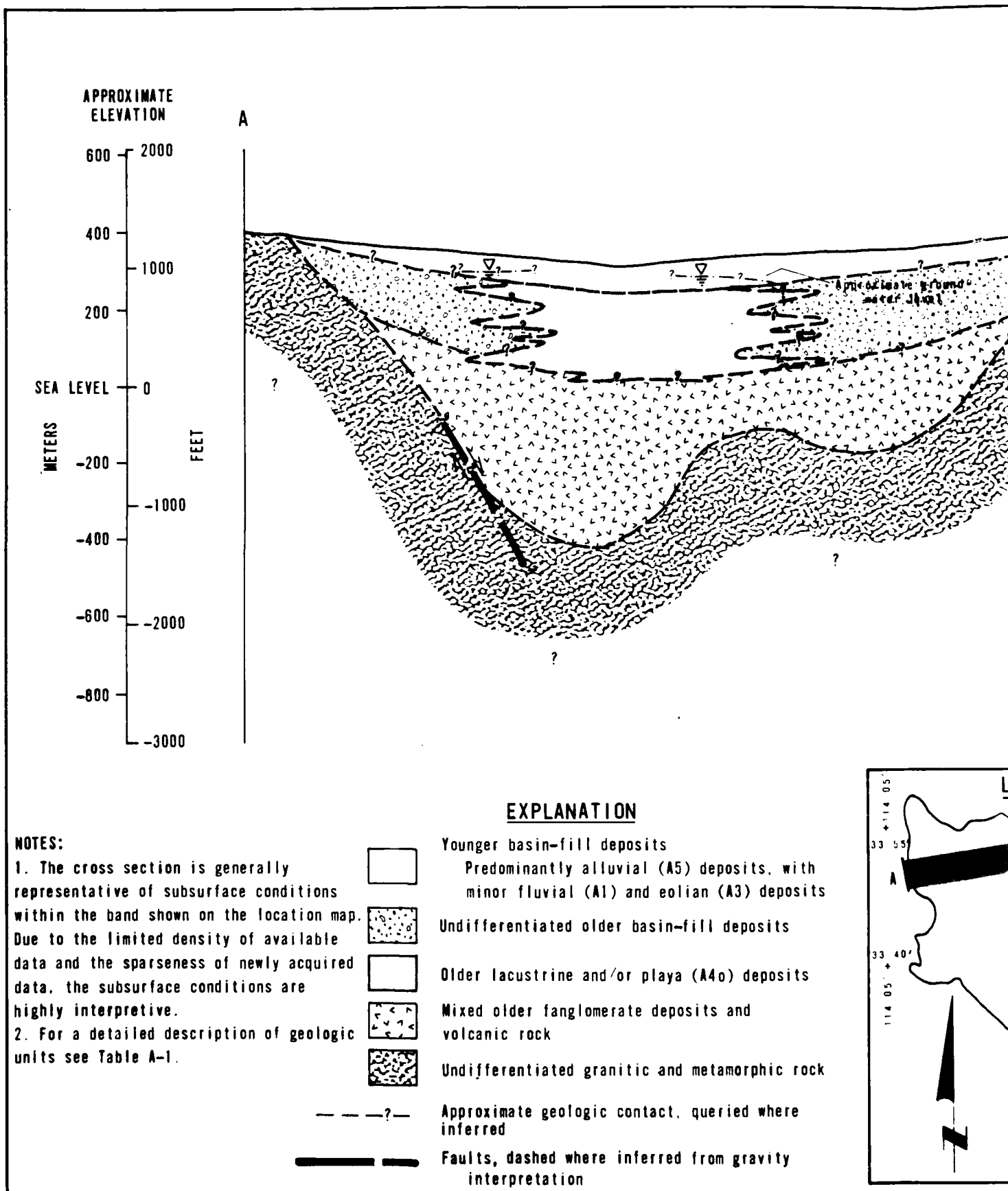


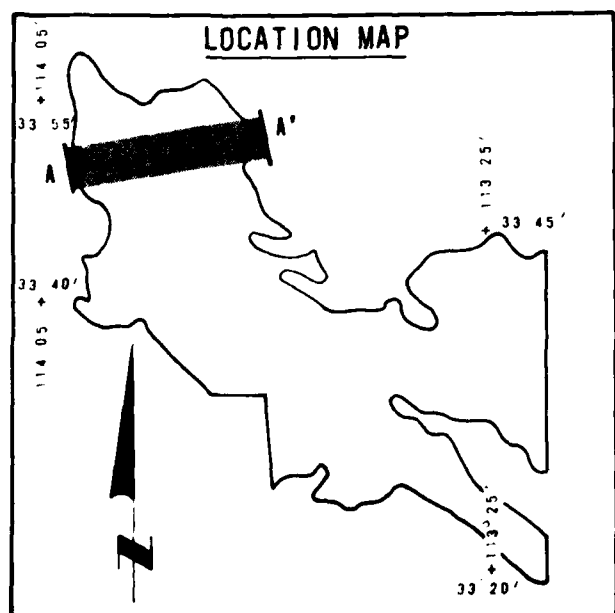
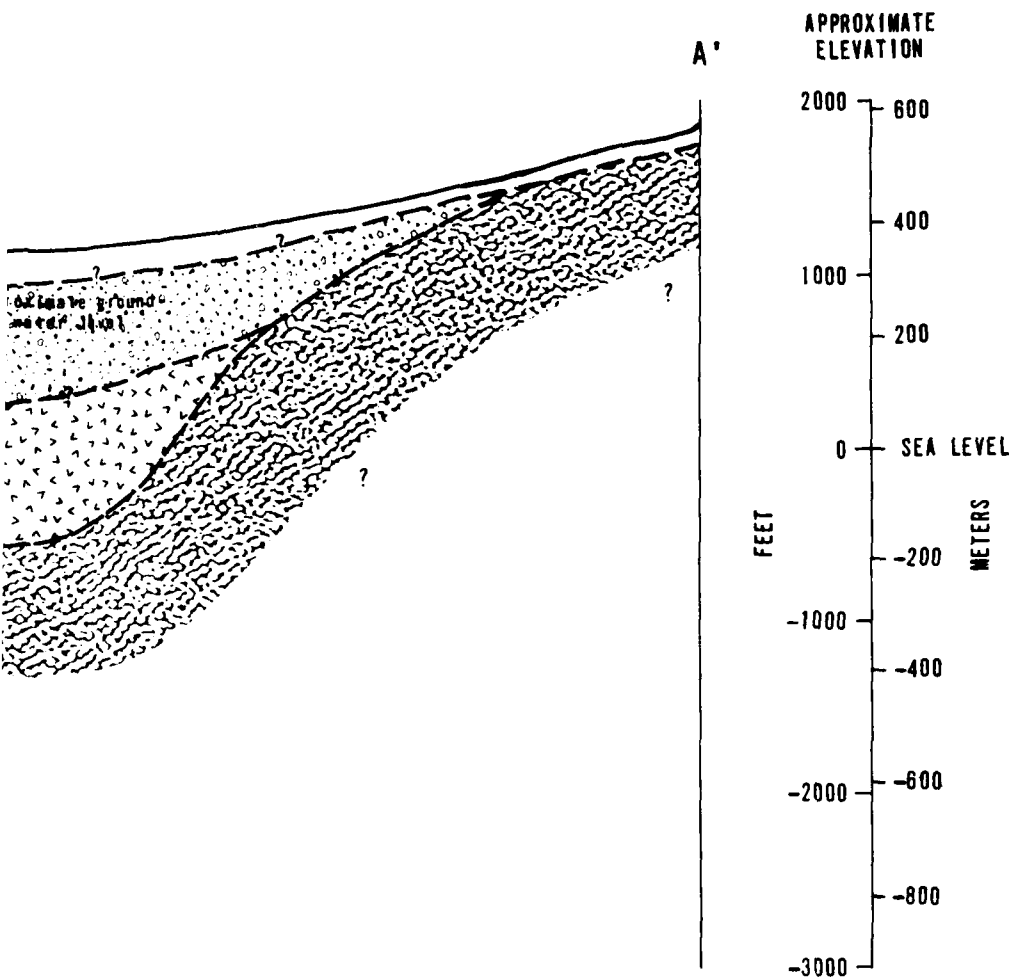
SOIL PROFILE B-B' RANEGRAS PLAIN, ARIZONA SONORAN CSP	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - SAMSO	FIGURE 4

FURRO NATIONAL INC.

3



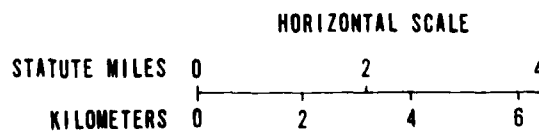




Horizontal Scale: 1" \approx 2 Miles (3.2 km)

Vertical Scale: 1" = 1000' (300 m)

Vertical Exaggeration: 10.5x



GENERALIZED GEOLOGIC CROSS SECTION
RANEGRAS PLAIN, ARIZONA
SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE
6

FUGRO NATIONAL INC.

2.4 GEOPHYSICAL PROPERTIES

Results of the shallow seismic and conductivity surveys are presented in Tables 5 and 6, respectively. Seismic velocities generally ranged from 840 to 8900 fps (256 to 2713 mps) in the upper 150 feet (46 m) of the materials. Bedrock velocities (>7000 fps; 2134 mps) were observed at five of the fourteen locations, all near the basin margin. Average conductivity values for the upper 50 feet (15 m) of the site soils ranged from 0.003 to 0.055 mhos/m. Only one value (0.003 mhos/m at RP-R-19) was less than the minimum specified value of 0.004 mhos/m in the Fine Screening criteria.

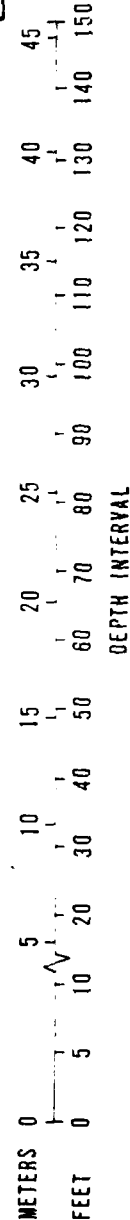
2.5 ENGINEERING PROPERTIES

Laboratory tests were performed to determine the engineering properties of soil samples obtained from the various geologic units. The testing program consisted of classification, consolidation, shear strength, compaction, CBR and chemical tests. The range of engineering and geophysical properties of the predominant geologic units is presented in Table 7.

Younger and intermediate alluvial fan deposits could not be differentiated at depth, and they were combined into one unit (A5) due to their similar grain size and engineering properties. These deposits consist predominantly of dense to very dense silty sands, gravelly sands, and sandy gravels which are only slightly compressible and have high shear strengths.

Older alluvial fan deposits occur only around the site periphery along mountain fronts. Their engineering properties were

SEISMIC LINE NO.	VELOCITY DISTRIBUTION FPS (MPS)		DEEPER REFRACTORS DEPTH	*ROCK EXCLUSION DEPTH TO 7000 FPS (2134 MPS)
RP-S-1	1150 (350)	4600 (1400)	-	-
RP-S-2	1150 (350)	5450 (1660)	-	70 (21)
RP-S-3	1300 (400)	3650 (1110)	-	90 (27)
RP-S-4	1400 (430)	4500 (1370)	-	-
RP-S-7	1050 (320)	4270 (1300)	-	-
RP-S-10	850 (260)	3500 (1070)	-	120 (37)
RP-S-11	1290 (390)	2920 (890)	-	120 (37)
RP-S-13	840 (260)	1600 (490)	-	153 (47)
RP-S-14	1280 (390)	3210 (980)	-	140 (43)
RP-S-15	1450 (440)	7000 (2130)	-	-
RP-S-16	1200 (370)	3000 (910)	-	-
RP-S-17	1720 (520)	3210 (980)	-	72 (22)
RP-S-18	1250 (380)	2150 (660)	-	130 (40)
RP-S-19	1330 (410)	2740 (840)	-	128 (39)



* If no refracting interface or layer with a velocity greater than 7000 fps (rock/rock-like material) was detected, a rock exclusion depth calculation was performed to determine the minimum depth at which rock could occur.

SHALLOW SEISMIC REFRACTION RESULTS
RANEGRAS PLAIN, ARIZONA
SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE
5

FUGRO NATIONAL, INC.

ACTIVITY LOCATION*	AVERAGE CONDUCTIVITY (mhos/m)**
R-1	.055
R-2	.023
R-3	.045
R-4	.020
R-7	.016
R-10	.029
R-11	.026
R-13	.019
R-14	.010
R-15	.032
R-16	.053
R-17	.043
R-18	.024
R-19	.003

*Resistivity was determined using a Schlumberger Array at each location where a seismic refraction survey was conducted.

**Conductivity is the inverse of resistivity. Numbers presented are the average of values determined to a depth of 50 feet, computed as follows:

$$\text{Average Conductivity} = (C_1 t_1 + C_2 t_2 + \dots + C_n t_n) / 50 \text{ feet}$$

Where

Average Conductivity = mhos/m

C_1 through C_n = Conductivity (mhos/m) of layers 1 through n

t_1 through t_n = Thickness (feet) of layers 1 through n to 50 feet

CONDUCTIVITY SURVEY RESULTS
RANEGRAS PLAIN, ARIZONA
SONORAN CSP

VEGETATION INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSC

TABLE
6

FUGRO NATIONAL, INC.

ENGINEERING AND GEOPHYSICAL PROPERTIES		A5
UNIFIED SOIL CLASSIFICATION SYMBOL(S)		SM, SP, GM, ML
GENERAL PROPERTIES		
DRY DENSITY	pcf(kg m ³)	84.3-135.6
MOISTURE CONTENT	(%)	0.4-26.4
DEGREE OF SATURATION	(%)	6.3-90.1
SPECIFIC GRAVITY		2.68-2.71
DEGREE OF CEMENTATION		Weak to strong
COMPRESSIONAL WAVE VELOCITIES	fps(mps)	
ELECTRICAL CONDUCTIVITY	(mhos m)	
GRAIN SIZE DISTRIBUTION (%)		
BOULDERS >12 inches (30cm)		0
COBBLES 3 to 12 inches (8 to 30cm)		0
GRAVEL		0-98
SAND		0-100
SILT AND CLAY		0-96
PLASTICITY DATA		
LIQUID LIMIT		24-54
PLASTICITY INDEX		3-27
COMPRESSIBILITY DATA		
COMPRESSION AT 4 ksf (192 kN m ²)	(%)	1-3%
SWELL OR COLLAPSE UPON SATURATION	(%)	0-1% Collapse
SHEAR STRENGTH DATA		
UNCONFINED COMPRESSION	ksf(kN m ²)	0.4-25.5
CD TRIAXIAL COMPRESSION		C = 0-1 ksf (0-48 kN m ²) $\phi = 30^{\circ}$ -40°
DIRECT SHEAR	ksf(kN m ²)	0.5-2.3
COMPACTION AND CBR DATA		
MAXIMUM DRY DENSITY	pcf(kg m ³)	128.8-130.2
OPTIMUM MOISTURE CONTENT	(%)	9.0-9.2
CBR AT 90% RELATIVE COMPACTION		20-30

GEOLOGIC UNITS

A4

CL. SC. CH

94.4-116.2

3.6-27.3

15.80-102.30

2.68

Weak to strong

0

0

0

2-23

77-98

28-56

9-34

1"

7" Swell

10.9-15.3

C = 3-5 ksi (144-240 kn m²) θ = 15-25°

0

0

0

0

RANGE OF ENGINEERING AND
GEOPHYSICAL PROPERTIES
RANEGRAS PLAIN, ARIZONA, SONORAN CSP

VI SITE INVESTIGATION
DEPARTMENT OF THE AIR FORCE LAMSC

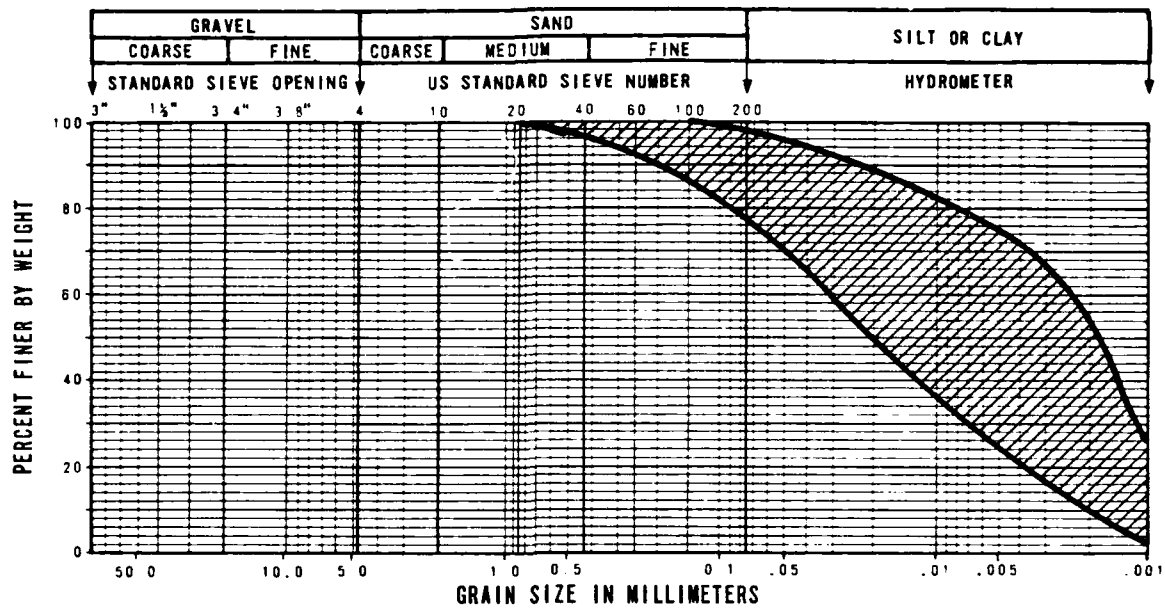
TABLE
7

FUGRO NATIONAL INC.

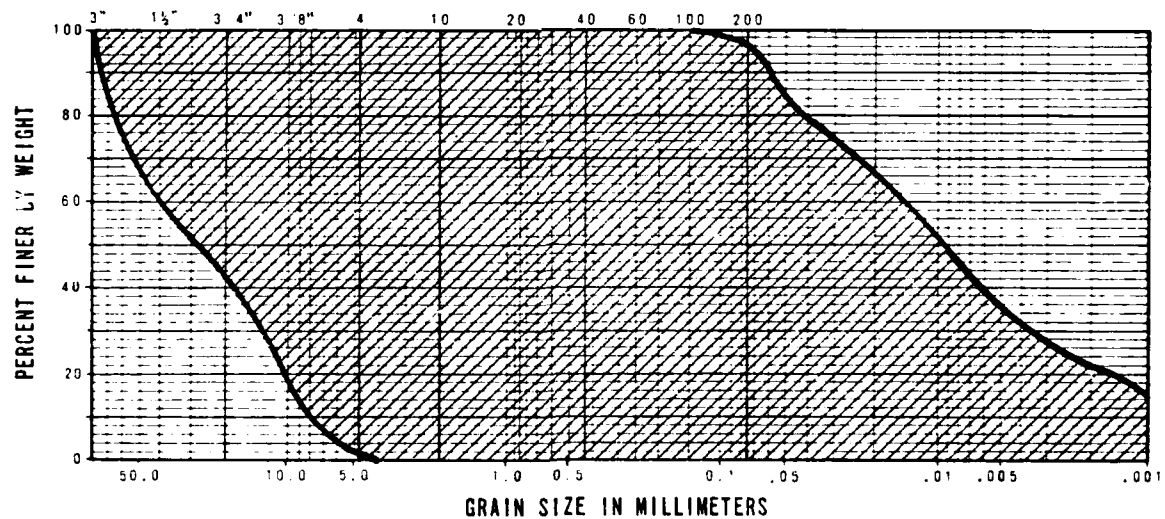
combined with younger and intermediate alluvial fan deposits due to very limited data. These deposits consist predominantly of gravels which are relatively incompressible and have very high shear strengths. In general, the alluvial fan deposits are neither expansive nor collapsible.

Playa deposits are predominantly stiff to very stiff clays and silty clays which are expansive when saturated, only slightly compressible, and have high shear strengths.

The gradation range of the combined geologic units are shown in Figure 7. Representative logs of three borings and three trenches are contained in Appendix B. Results of the shear strength, CBR and chemical tests performed on samples from the site and a summary of all laboratory tests performed on soil samples obtained from boring RP-B-15 are also included in Appendix B.



A4



A5, A1

RANGE OF GRADATION OF GEOLOGIC UNITS
RANERGRAS PLAIN, ARIZONA
SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE
7

GENERAL NATIONAL

3.0 MOJAVE SITE

The Mojave Characterization site covers an area of 476 nm² (1636 km²) in central San Bernardino County, California. The site consists of a group of adjacent valleys including parts of Mojave, Broadwell, and Cronese valleys and the southern Devil's Playground. The area lies between Interstate Highways 15 and 40 east of Barstow, California. Unpaved county roads and various pipeline, powerline, and railroad service roads provide access within the site.

3.1 SCOPE OF INVESTIGATION

Scope of geologic, geophysical, and soils engineering field activities performed at the site and laboratory tests performed on soil samples from the site are presented in Table 8. Detailed information about the soils engineering field activities (ten borings and ten trenches) is summarized in Tables 9 and 10. Locations of all the field activities are shown in Figure 8.

3.2 SURFICIAL GEOLOGY AND TERRAIN

The predominant surficial geologic units in the Mojave site are younger and intermediate age alluvial fans (Figure 8). These units cover 43 and 27 percent of the site, respectively. Eolian deposits cover 17 percent of the site. Fluvial, playa, and older alluvial fan deposits constitute the remaining 13 percent.

Younger alluvial fan, fluvial, and playa deposits occur in central basin areas. Intermediate and older alluvial fan

GEOLOGY AND GEOPHYSICS

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geological Mapping Stations	51
Shallow Refraction	15
Electrical Conductivity	10

ENGINEERING

NUMBER OF BORINGS	NOMINAL DEPTH FEET (METERS)
2	25 (8)
8	50 (15)
NUMBER OF TRENCHES	NOMINAL DEPTH FEET (METERS)
3	13 (4)
7	15 (5)

ENGINEERING-LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture Density	67/19
Specific Gravity	5
Sieve Analysis	75
Hydrometer	59
Atterberg Limits	4
Consolidation	0

TYPE OF TEST	NUMBER OF TESTS
Unconfined Compression	7
Triaxial Compression	0
Direct Shear	21
Compaction	5
CBR	2
Chemical Analysis	4

SCOPE OF FIELD AND LABORATORY
ACTIVITIES

MOJAVE, CALIFORNIA, SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SANSOTABLE
8**FUGRO NATIONAL, INC.**

BORING NUMBER	TOTAL DEPTH FEET (METERS)	TYPE OF DRILL RIG USED	TYPE OF SAMPLES* OBTAINED
MJ-B-1	41.0 (12.5)	Hollow Stem Auger	B,D
MJ-B-4	21.0 (6.4)	Hollow Stem Auger	B,D,SS
MJ-B-5	35.0 (10.7)	Hollow Stem Auger	B,D
MJ-B-6	6.0 (1.8)	Hollow Stem Auger	D
MJ-B-12	50.5 (15.4)	Hollow Stem Auger	B,SS
MJ-B-13	50.0 (15.2)	Hollow Stem Auger	B,D,SS
MJ-B-14	50.5 (15.4)	Hollow Stem Auger	B,P
MJ-B-15	51.0 (15.5)	Hollow Stem Auger	B,D,SS
MJ-B-16	50.3 (15.3)	Hollow Stem Auger	B,D,SS
MJ-B-17	51.0 (15.5)	Hollow Stem Auger	B,SS

- * P Pitcher sample (undisturbed)
D Fugro Drive sample (relatively undisturbed)
B Bulk sample (disturbed)
SS Split Spoon sample (disturbed)

ENGINEERING FIELD ACTIVITIES - BORINGS
MOJAVE, CALIFORNIA
SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

TABLE
9

FUGRO NATIONAL, INC.

TRENCH NUMBER	TOTAL DEPTH FEET(METERS)	STABILITY OF VERTICAL EXCAVATION WALLS
MJ-T-1	15 (4.6)	Stable
MJ-T-2	14.5 (4.4)	Stable
MJ-T-3	13.6 (4.1)	Stable
MJ-T-4	13.0 (4.0)	Unstable, walls caved
MJ-T-5	14.9 (4.5)	Stable, some sloughing
MJ-T-6	13.7 (4.2)	Stable, some sloughing in the upper 2' (0.6m)
MJ-T-7	13.2 (4.0)	Stable, some sloughing in the upper 3' (0.9m)
MJ-T-8	14.8 (4.5)	Stable, some sloughing
MJ-T-9	13.9 (4.2)	Stable
MJ-T-10	12.5 (3.8)	Stable

ENGINEERING FIELD ACTIVITIES - TRENCHES
MOJAVE, CALIFORNIA
SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

TABLE
10

FUGRO NATIONAL, INC.

EXPLANATION

SYMBOLS

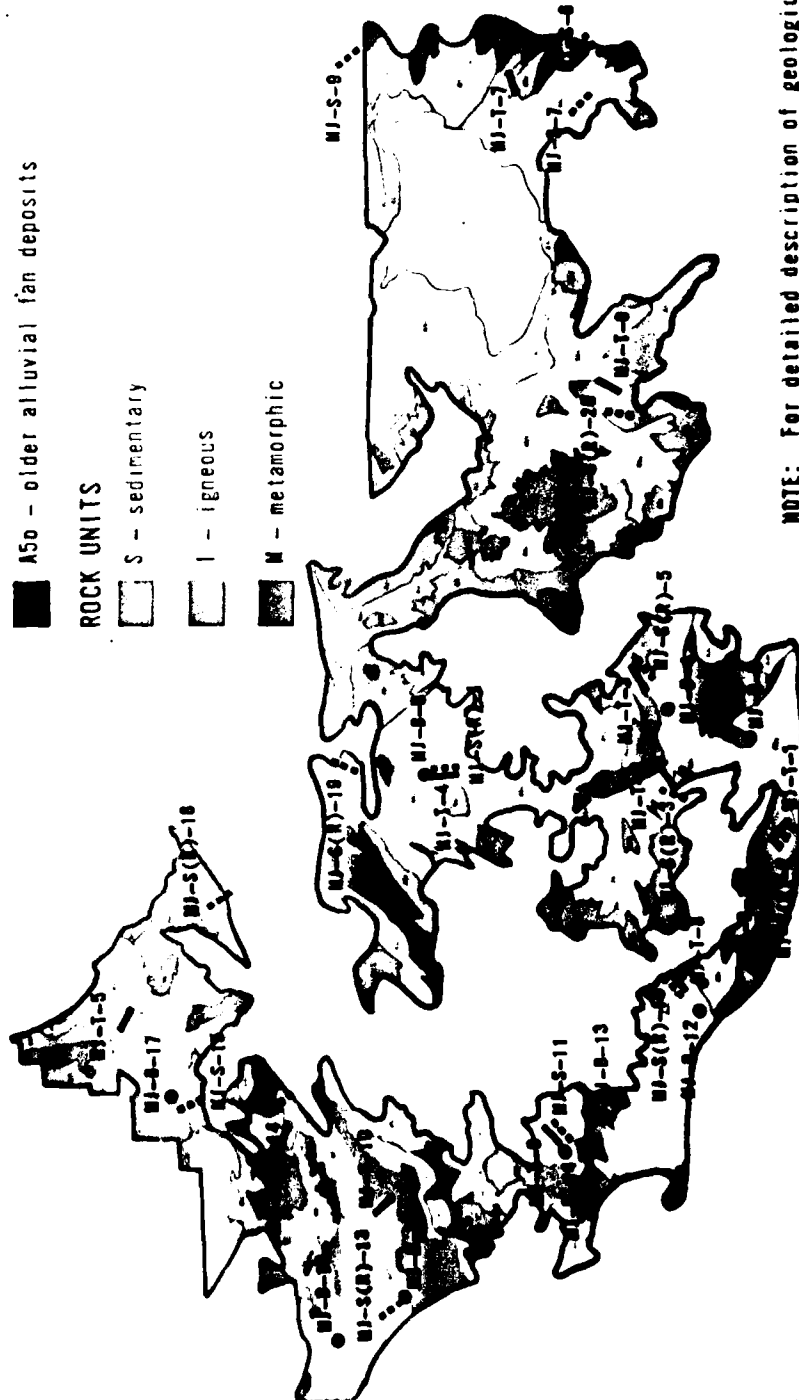
- Boring
- Shallow Seismic Refraction Line
- S(0) Both Shallow Seismic and Resistivity (Conductivity) Lines
- Trench

SURFICIAL GEOLOGIC UNITS

- A1 and A3 - stream channel and eolian deposits
- A4 - plays and lacustrine deposits
- A5y - younger alluvial fan deposits
- A5i - intermediate alluvial fan deposits
- A5o - older alluvial fan deposits

ROCK UNITS

- S - sedimentary
- I - igneous
- M - metamorphic



NOTE: For detailed description of geologic units, see Table A-1

GENERALIZED GEOLOGIC MAP AND FIELD ACTIVITY LOCATIONS MOJAVE, CALIFORNIA, SONORAN CSP

MOJAVE INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSU

FIGURE
8

USERO NATIONAL INC.

deposits occur adjacent to the mountain front areas around the periphery of each valley. Playa deposits at the surface occur principally in Broadwell and Cronese lakes (dry lakes) and in the deposits of Pleistocene Lake Mannix in the northwestern part of the site. Mappable fluvial deposits also occur in the northwestern part of the site along the Mojave River. Although a thin veneer of eolian sand is present over much of the western part of the site adjacent to Mojave Valley, the principal concentration of eolian sand is in the Kelso Dunes-Devil's Playground area to the east.

Alluvial fan deposits range from sands and gravelly sands in basin areas to sandy gravels near mountain fronts. Fluvial and eolian deposits are poorly graded sands and playa deposits consisting of clay with minor silt and sand interbeds.

Surface slopes and depths of drainage incision vary with geologic unit, both increasing with proximity to mountain fronts. Maximum surface slope generally does not exceed ten percent except in dune areas and along drainages. Typical slopes on alluvial fan surfaces range from three to six percent but steeper slopes are not uncommon. Depths of incision (excluding older alluvial fan deposits) can be as deep as 32 feet (10 m) but typical depths are less than three feet (1 m). A summary of soil and terrain conditions for each geologic unit is given in Table 11.

SURFICIAL GEOLOGIC UNIT (a)	GEOLOGIC AGE	THICKNESS FEET (METERS)	DESCRIPTIVE NAME(S)	USCS SYMBOL(S)	AREAL EXTENT (SITE)		GRAI
					nm ² (km ²)	PERCENT	
Fluvial Deposits (A1)	Quaternary	Unknown	Gravelly Sand, Sand	SP	9 (31)	2	P Mode W
Eolian Dune (A3d) and Sheet (A3s) Sand Deposits	Quaternary	0-550 (0-168)	Sand	SP	82 (282)	17	P
Playa Deposits (A4)	Quaternary	Unknown	Silty Sand, Sandy Silt, Clay	SM, ML-CL	6 (21)	1	Mode W
Older Playa Deposits (A4o)	Quaternary	Unknown	Silty Sand, Silt, Clay	SM, ML-CL	5 (17)	1	P
Younger Alluvial Fan Deposits (A5y)	Quaternary	Unknown	Silty Sand, Gravelly Sand	SM, SP	203 (697)	43	Mode W
Intermediate Alluvial Fan Deposits (A5i)	Quaternary	Unknown	Silty Sand, Gravelly Sand	SM, SP	126 (433)	27	Mode W
Older Alluvial Fan Deposits (A5o)	Quaternary- Tertiary	Unknown	Sandy Gravel, Silty to Gravelly Sand	GP, SM-SP	45 (155)	9	Mode W

NOTES:

- (a) For generic description of geologic units, see Table A-1.
 (b) For description of stage of caliche, see Figure A-1.
 (c) Commonly covered by a veneer of eolian sand, particularly in the western part of the site

EXTENT (SITE)		PROPERTIES OF SURFACE MATERIALS					SURFACE MORPHOLOGY		NOTES
km ²	PERCENT	GRADATION	CEMENTATION	MAXIMUM GRAIN SIZE	PAVEMENT/PATINA	STAGE OF CALICHE (b)	SLOPE (PERCENT)	DRAINAGE DEPTHS FEET (METERS)	
	2	Poor-Moderately Well	None	Boulder	None	None	<1-3	0-3 (0-1)	
	17	Poor	None	Sand	None	None	0-60	0-3 (0-1)	
	1	Moderately Well	Weak	Gravel	None	None	0	None	
	1	Poor	Weak	Sand	None	None	0-10	6-10 (2-3)	
	43	Moderately Well	Weak	Boulder	None	None-I	2-6	0-1 (0-0.3)	
	27	Moderately Well	Weak-Moderate	Boulder	Fair-Well/Poor	I-II	2-10	3-10 (1-3)	(c)
	9	Moderately Well	Moderate	Boulder	None	II-III	4-40	30-130 (10-40)	

DESCRIPTION OF SURFICIAL
GEOLOGIC UNITS
MOJAVE, CALIFORNIA, SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

TABLE
11

FUGRO NATIONAL, INC.

3.3 SUBSURFACE CONDITIONS

3.3.1 Soil Profiles

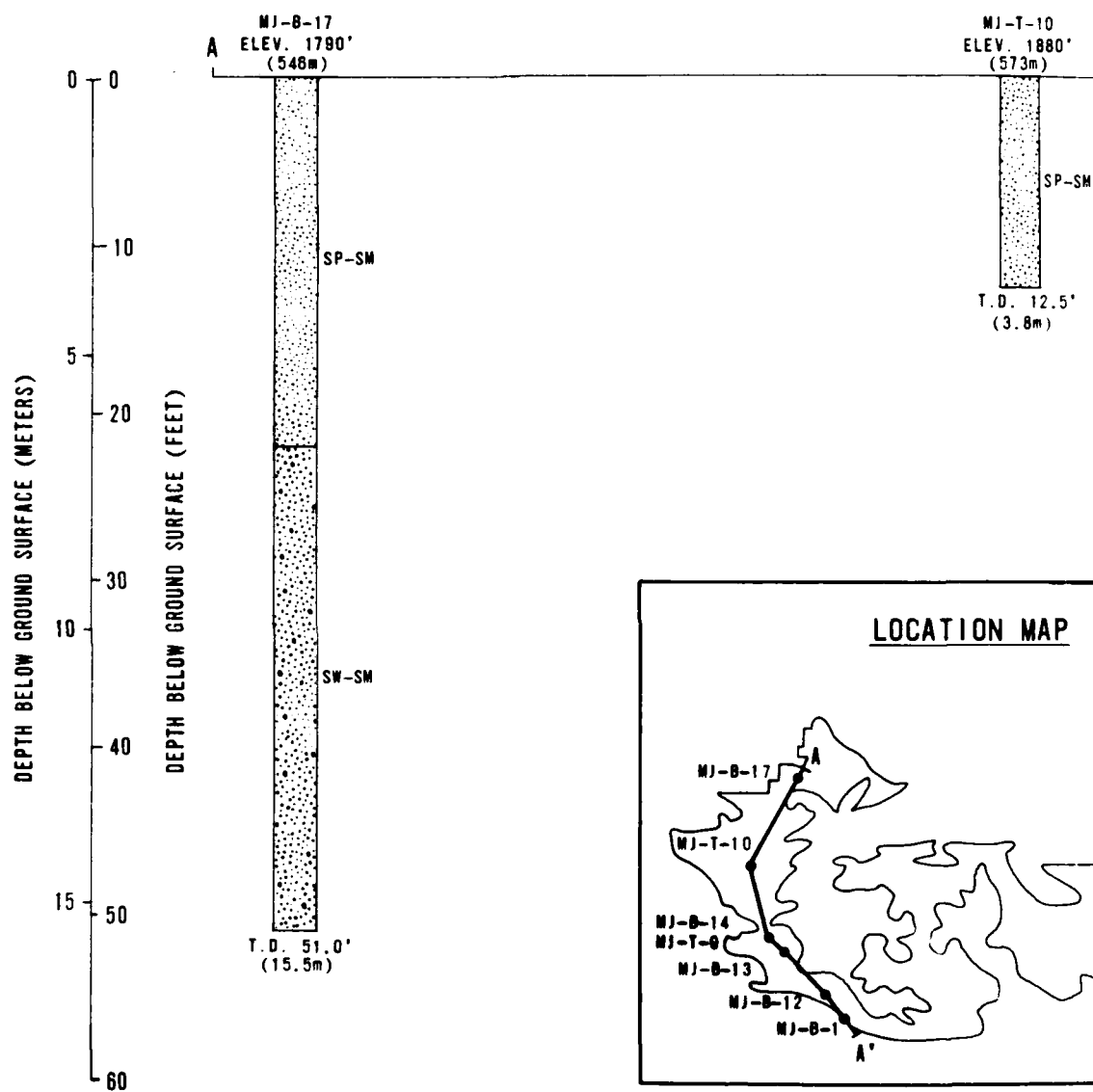
Sands and gravels are the predominant soil types in the Mojave site. The distribution of these soils are presented by two soil profiles shown in Figures 9 and 10. Some fine grained soils exist in the playa and fluvial deposits, generally in central basin areas. Cobbles and boulders are generally not encountered, except in the proximity of mountain fronts.

3.3.2 Depth to Shallow (<150 Feet; 46 m) Rock and Water

Figure 11 shows portions of site in which rock and water are estimated to be encountered within a depth of 150 feet below ground surface. Shallow rock comprises approximately ten percent of the site based on interpretation from borings, seismic surveys, gravity surveys, surface outcrops, topography, and geologic mapping. Ground water occurs at depths less than 150 feet (46 m) over approximately five percent of the site, concentrated in the western portion along the Mojave River and around Broadwell Lake. Ground-water data are sparse in the remainder of the site, however, water depths are generally thought to be greater than 150 feet (46 m) deep.

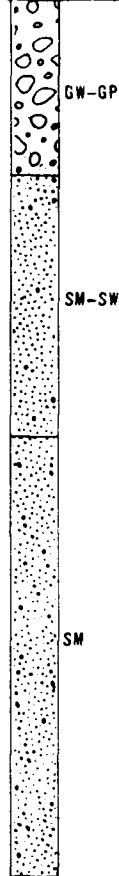
3.3.3 Basin Configuration

Gravity interpretation was used to approximate thickness of alluvial basin fill deposit for five separate basins within the Mojave siting area (Figure 11). Approximately 2000 feet (610 m) is the average depth to the bedrock complex in these basins. Between Briston Mountain and Granite Mountain, depth



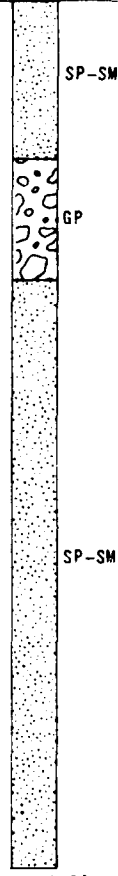
- NOTES:
1. Ground surface elevations shown at locations of borings are approximate.
 2. T.D. Total Depth
 3. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix

MJ-B-14, MJ-T-9
ELEV. 2380'
(719m)



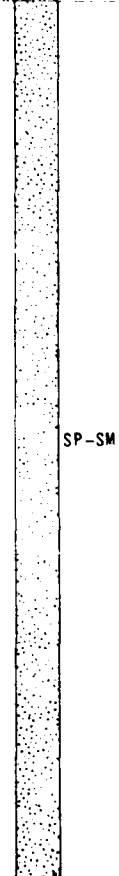
T.D. 50.5'
(15.4m)

MJ-B-13
ELEV. 2200'
(671m)



T.D. 50.0'
(15.2m)

MJ-B-12
ELEV. 2190'
(667m)

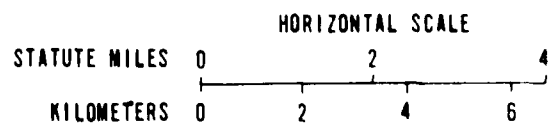
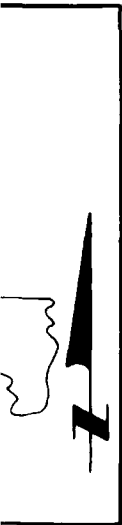


T.D. 50.5'
(15.4m)

MJ-B-11
ELEV. 2180'
(664m)



T.D. 50.0'
(15.2m)



ings are approximate

Unified Soil Classification System

7

3
00'

SP-SM

IP

P-SM

)'

MJ-B-12
ELEV. 2190'
(667m)

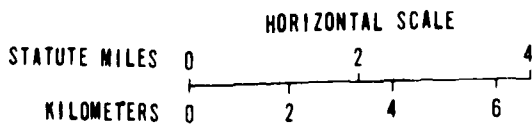
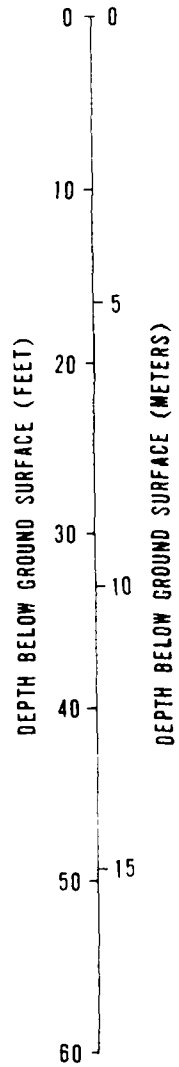
MJ-B-1
ELEV. 2220'
(677m) A

SP-SM

SP-SM

T.D. 41.0'
(12.5m)

T.D. 50.5'
(15.4m)

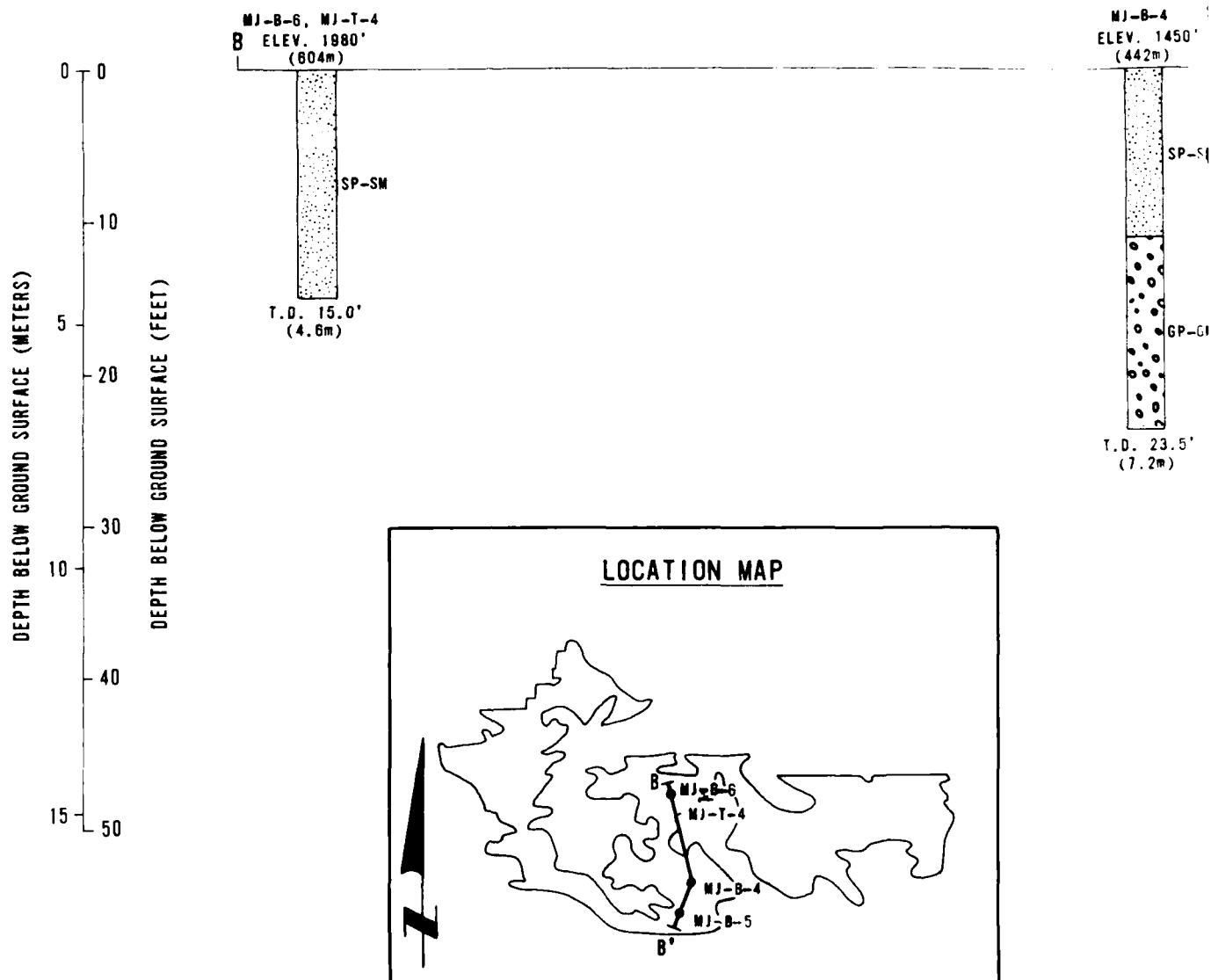


3 SOIL PROFILE A-A'
MOJAVE, CALIFORNIA
SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSU

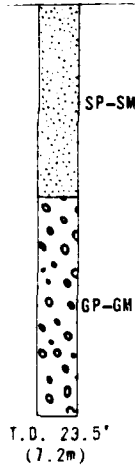
FIGURE
9

TUBRO NATIONAL, INC.

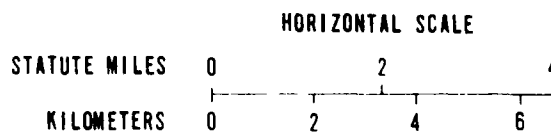
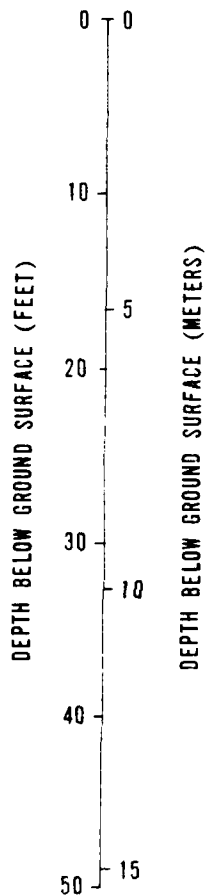
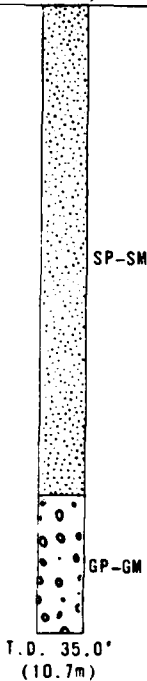


- NOTES:
1. Ground surface elevations shown at locations of borings are approximate
 2. T.D. Total Depth
 3. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix

MJ-B-4
ELEV. 1450'
(442m)



MJ-B-5
ELEV. 1450'
(442m)



SOIL PROFILE B-B'
MOJAVE, CALIFORNIA
SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS

FIGURE
10

FURRO NATIONAL INC.

2

ximate

Classification System

SYMBOLS

~1000~



1:500,000
1" = 8 Miles

- Contour indicates approximate depth to granitic and metamorphic rock, contour interval 1000 feet. Subsurface depths and configuration based on gravity interpretation.
- Contour indicates sedimentary, igneous, and metamorphic rock or rock-like material with p-wave velocities > 7000 fps at a depth of approximately 150 feet (hachured side of line indicates rock at <150 feet). Contour location based on geologic mapping and geophysical interpretation.
- Contour indicates ground water at a depth of approximately 150 feet (hachured side of line indicates water at <150 feet).

EXPLANATION

SURFICIAL GEOLOGIC UNITS

- ☐ A1 and A3 - fluvial and eolian deposits
- ☐ A4 - playa and lacustrine deposits
- ☐ A5y - younger alluvial fan deposits
- ☐ A5i - intermediate alluvial fan deposits
- ☐ A5o - older alluvial fan deposits

ROCK UNITS

- ☐ S - sedimentary
- ☐ I - igneous
- ☐ M - metamorphic



NOTE: For detailed description of geologic units, see Table A-1.

FAULTS 34°45' N

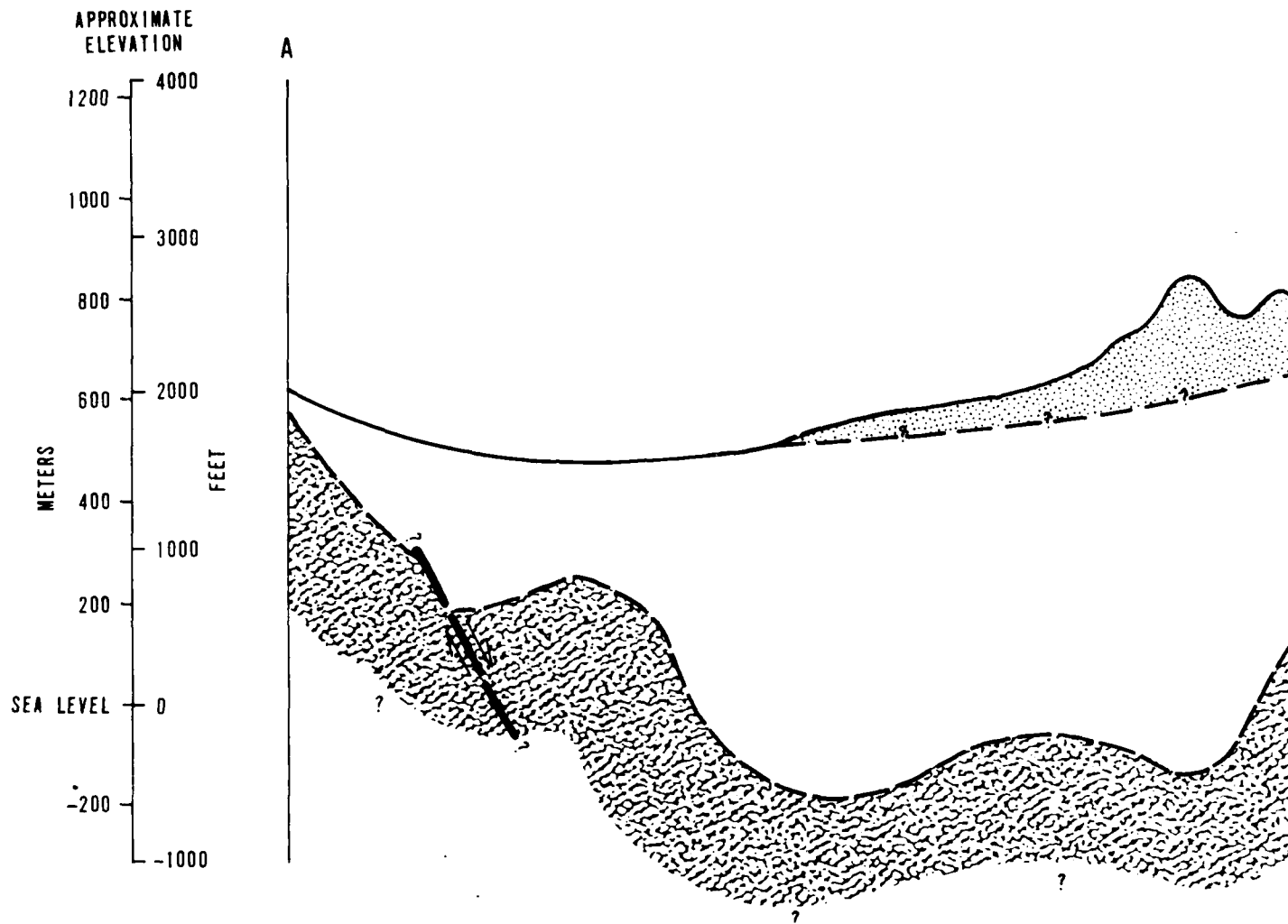
.....? Dashed where approximately located from gravity interpretation; all other faults from Jennings, C.W., 1977, Geologic Map of California: C.D.M.G., 1:750,000

GENERALIZED GEOLOGIC MAP AND
SELECTED SUBSURFACE FEATURES
MOJAVE, CALIFORNIA, SONORAN CSP






MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS0

FIGURE
11

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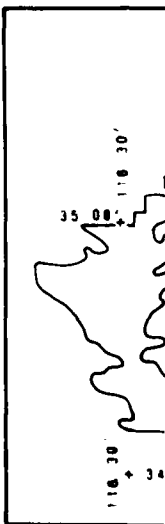


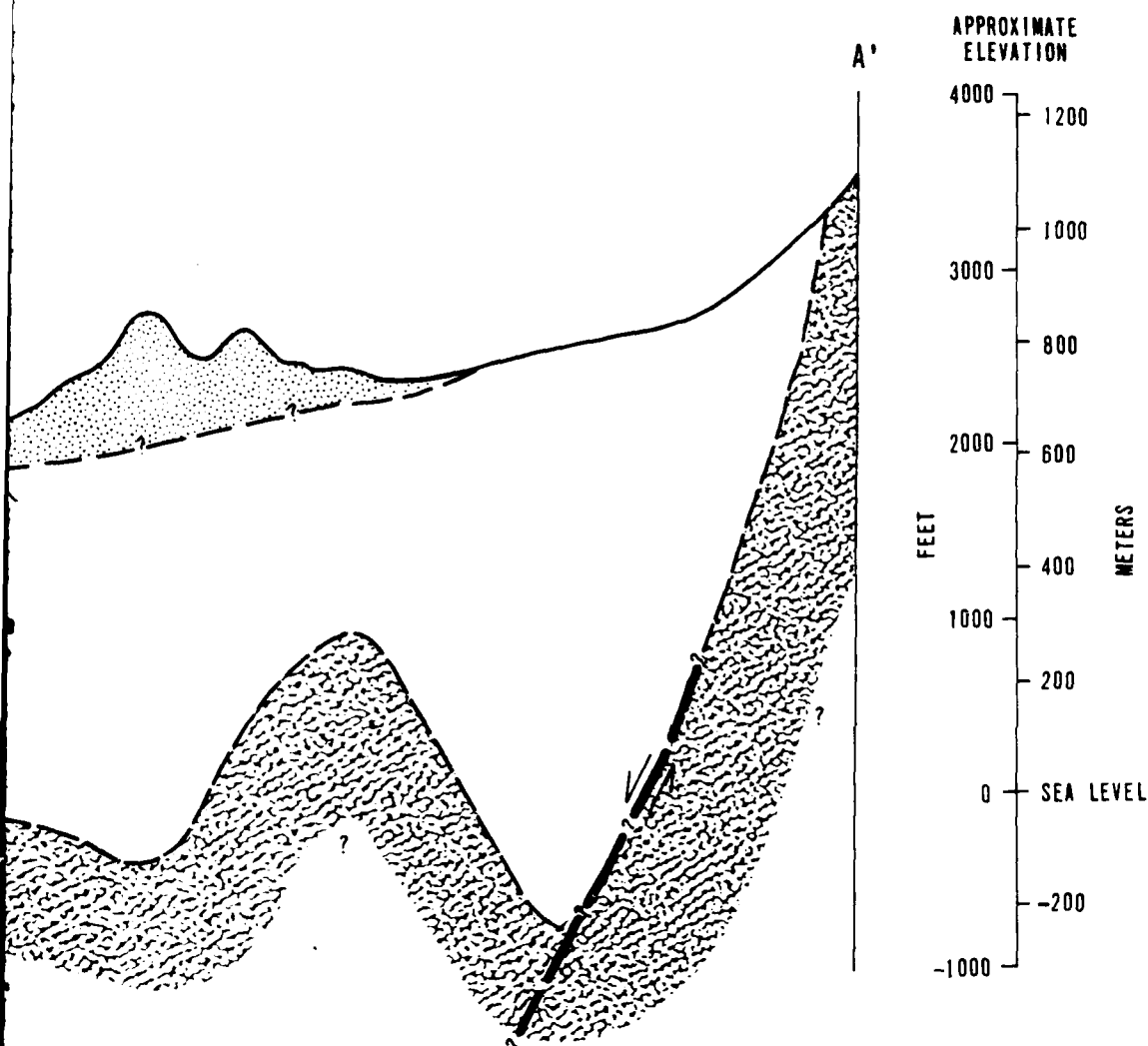
EXPLANATION

-  Eolian dune (A3d) and sheet (A3s) sand deposits
-  Undifferentiated basin-fill deposits
Predominantly alluvial (A5) deposits, age typically increases with depth, but data is insufficient to divide younger and older material
-  Undifferentiated granitic and metamorphic rock
-  Approximate geologic contact, queried where inferred
-  Fault, dashed where inferred from gravity interpretation, or from Jennings, C. W., 1977, Geologic Map of California: C.D.M.G. 1:750 000

NOTES: 1. The cross section is generally representative of subsurface conditions within the band shown on the location map. Due to the limited density of available data and the sparseness of newly acquired data, the subsurface conditions are highly interpretive.

2. For a detailed description of geologic units see Table A-1.

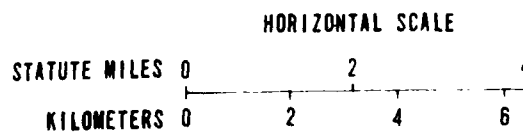
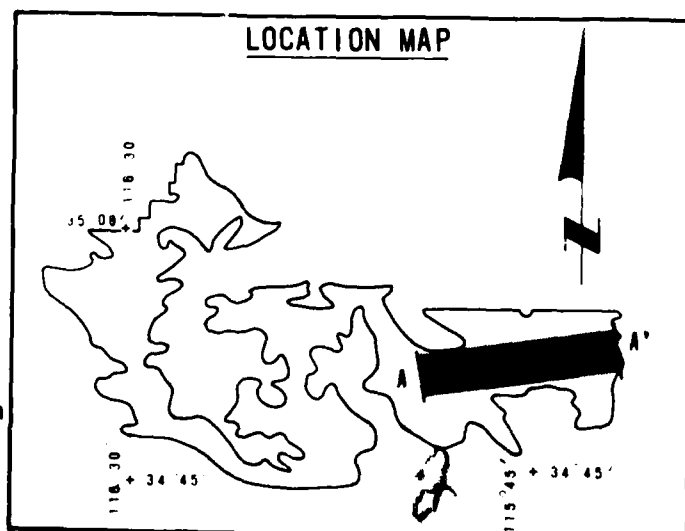




Horizontal Scale: 1" \approx 2 Miles (3.2 km)

Vertical Scale: 1" = 1000' (300 m)

Vertical Exaggeration: 10.5x



**GENERALIZED GEOLOGIC CROSS SECTION
MOJAVE, CALIFORNIA
SONORAN CSP**

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSQ

FIGURE
12

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to bedrock is about 2400 feet (730 m). The deepest basin interpreted is north of Granite Mountain and indicates a depth of 4000 feet (1219 m) overlain by basin-fill deposits.

3.4 GEOPHYSICAL PROPERTIES

Results of the shallow seismic refraction and conductivity surveys are presented in Tables 12 and 13, respectively. Seismic velocities in the upper 150 feet (46 m) ranged from 950 to 16,300 fps (290 to 4970 mps). The low velocity (<2000 fps; 610 mps) surficial unit is unusually thick at this site with a maximum thickness of 80 feet (24 m) observed in the northwestern part (MJ-S-13) where a thick sequence of older playa deposits occurs. Bedrock velocities (>7000 fps; 2134 mps) were observed at two sites at depths less than 150 feet (46 m). Average conductivities for the upper 50 feet (15 m) of the site soils ranged from 0.005 to 0.035 mhos/meter and exceed the minimum value of 0.004 mhos/m specified in the Fine Screening criteria.

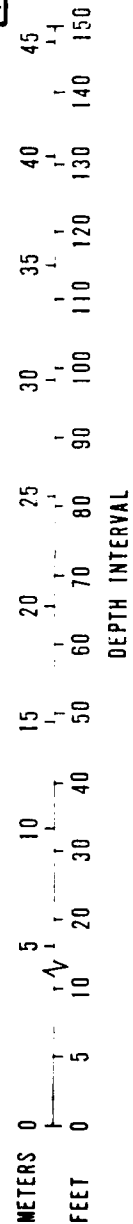
3.5 ENGINEERING PROPERTIES

Laboratory tests were performed to determine the engineering properties of soil samples obtained from the various geologic units. The testing program consisted of classification, consolidation, shear strength, compaction, CBR, and chemical tests. The range of engineering and geophysical properties of predominant geologic units is presented in Table 14.

Younger and intermediate alluvial fan deposits could not be differentiated at depth, and they were combined into one unit (A5) due to their similar grain size and engineering properties.

SEISMIC LINE NO.	VELOCITY DISTRIBUTION FPS (MPS)										DEEPER REFRACTORS DEPTH VELOCITY	* ROCK EXCLUSION DEPTH TO 7000 FPS (2134 MPS)
MJ-S-1	(a)	1720 (524)	2420 (740)	6000 (1830)							-	140 (43)
MJ-S-2		2250 (690)	5400 (1650)								-	100 (30)
MJ-S-3		1850 (560)	3000 (910)								-	184 (56)
MJ-S-5		1450 (440)	2500 (760)								-	136 (41)
MJ-S-6		1200 (370)	4340 (1320)	16300 (4970)							-	-
MJ-S-7		950 (290)	3400 (1040)								-	120 (37)
MJ-S-9		1550 (470)	4500 (1370)	5400 (1650)							-	100 (30)
MJ-S-10	(b)	2100 (640)	2800 (850)	8600 (2620)							-	-
MJ-S-11		1500 (460)	2340 (710)	5520 (1680)							-	137 (42)
MJ-S-13		1370 (420)	1990 (610)	5860 (1790)							-	148 (45)
MJ-S-14		1500 (460)	2400 (730)								-	142 (43)
MJ-S-15		1450 (440)	3920 (860)	6580 (2010)							-	91 (28)
MJ-S-18		1320 (400)	1880 (570)	4720 (1440)							-	89 (27)
MJ-S-19		1380 (420)	5460 (1660)								-	80 (24)
MJ-S-20		1400 (430)	2000 (610)	4000 (1220)							-	175

NOTE: (a) 1150 (350) (b) 1000 (300)



* If no refracting interface or layer with a velocity greater than 7000 fps (rock/rock-like material) was detected, a rock exclusion depth calculation was performed to determine the minimum depth at which rock could occur.

SHALLOW SEISMIC REFRACTION RESULTS MOJAVE, CALIFORNIA SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAWSO

TABLE
12

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ACTIVITY LOCATION*	AVERAGE CONDUCTIVITY (mhos m)**
R-1	.020
R-2	.010
R-3	.010
R-5	.010
R-10	.007
R-13	.035
R-14	.028
R-18	.005
R-19	.019
R-20	.023

*Resistivity was determined using a Schlumberger Array at each location where a seismic refraction survey was conducted.

**Conductivity is the inverse of resistivity. Numbers presented are the average of values determined to a depth of 50 feet, computed as follows:

$$\text{Average Conductivity} = (C_1 t_1 + C_2 t_2 + \dots + C_n t_n) / 50 \text{ feet}$$

Where

Average Conductivity = mhos m

C_1 through C_n = Conductivity (mhos/m) of layers 1 through n

t_1 through t_n = Thickness (feet) of layers 1 through n to 50 feet

CONDUCTIVITY SURVEY RESULTS
MOJAVE, CALIFORNIA
SONORAN CSP

VEGETATING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSC

TABLE
13

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ENGINEERING AND GEOPHYSICAL PROPERTIES		A5
UNIFIED SOIL CLASSIFICATION SYMBOL(S)		SP-SM, SW-SM, GP-GM, SP, SW, SM
GENERAL PROPERTIES		
DRY DENSITY	pcf(kg m ³)	97.5-121.1
MOISTURE CONTENT	(%)	1.1-10.4
DEGREE OF SATURATION	(%)	9.5-62.0
SPECIFIC GRAVITY		2.58-2.63
DEGREE OF CEMENTATION		Weak to strong
COMPRESSIONAL WAVE VELOCITIES	fps(mps)	
ELECTRICAL CONDUCTIVITY	(mhos m)	
GRAIN SIZE DISTRIBUTION (%)		
BOULDERS >12 inches (30cm)		0
COBBLES 3 to 12 inches (8 to 30cm)		0
GRAVEL		0-75
SAND		0-98
SILT AND CLAY		2-59
PLASTICITY DATA		
LIQUID LIMIT		0
PLASTICITY INDEX		0
COMPRESSIBILITY DATA		
COMPRESSION AT 4 ksf (192 kN m ²)	(%)	0
SWELL OR COLLAPSE UPON SATURATION	(%)	0
SHEAR STRENGTH DATA		
UNCONFINED COMPRESSION	ksf(kN m ²)	0.4-1.9
CD TRIAXIAL COMPRESSION		0
DIRECT SHEAR	ksf(kN m ²)	0.1-4.2
COMPACTION AND CBR DATA		
MAXIMUM DRY DENSITY	pcf(kg m ³)	122.5-131.5
OPTIMUM MOISTURE CONTENT	(%)	8.8-9.5
CBR AT 90% RELATIVE COMPACTION		20

GEOLOGIC UNITS

	A4
SM	CH, CL
	88.7-104.1
	7.4-19.0
	25.6-57.1
	2.63
	Weak to strong
	0
	0
	0-6
	8-93
	7-88
	14-92
	24-59
	2-34
	0
	0
	3.2-12.5
	0
	0
	0
	0
	0

RANGE OF ENGINEERING AND
GEOPHYSICAL PROPERTIES
MOJAVE, CALIFORNIA, SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

TABLE
14

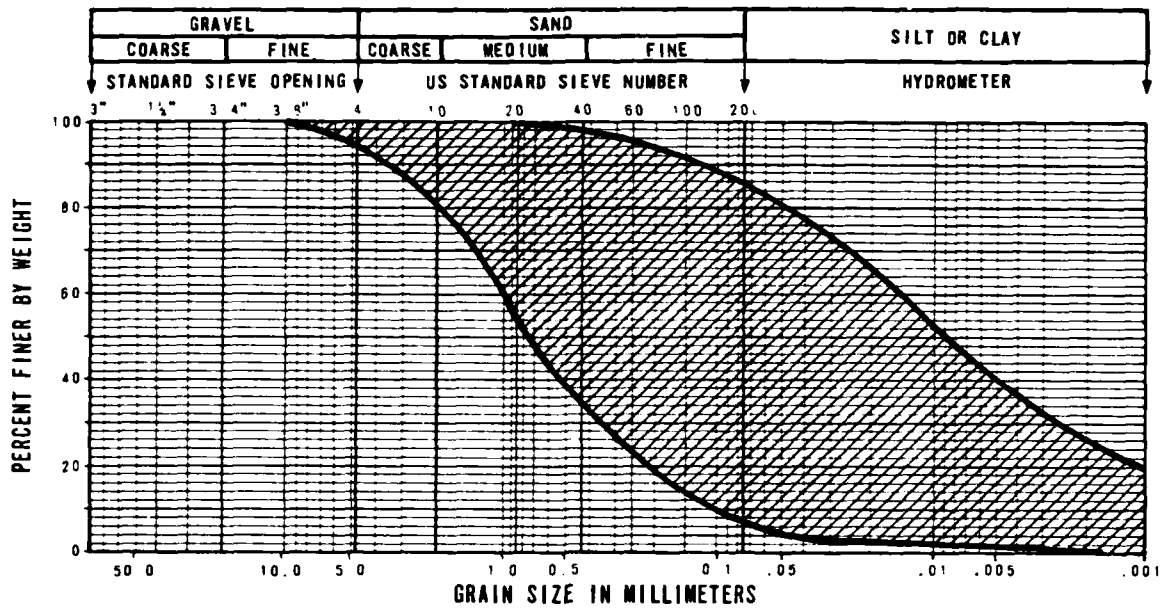
FUGRO NATIONAL, INC.

These deposits consist predominantly of dense sands and gravels which are only slightly compressible and have high shear strengths.

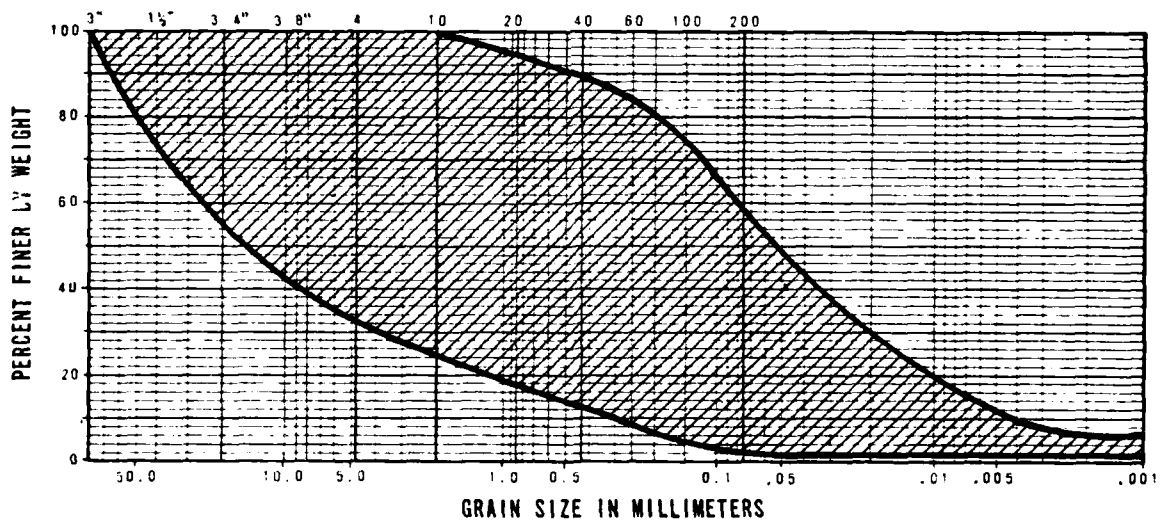
Older alluvial fan deposits occur along mountain fronts and are limited in extent. Their engineering properties were combined with younger and intermediate alluvial fan deposits due to insufficient data. These deposits consist predominatly of gravels which are relatively incompressible and have very high shear strengths.

Playa deposits were generally encountered in central basin areas. These deposits are predominantly stiff to very stiff clays and silty clays which may be expansive when saturated, are only slightly compressible and have high shear strengths.

The gradation ranges of the combined geologic units are shown in Figure 13. Table 15 includes the results of chemical tests which indicate the sulfate attack potential of soils on concrete ranges from "positive" to "severe". Representative logs of three borings and three trenches are contained in Appendix C. Results of the shear strength and CBR tests performed on samples from the site and a summary of all the laboratory tests performed on soil samples obtained from boring MJ-B-15 are also included in Appendix C.



A4



A5

RANGE OF GRADATION OF GEOLOGIC UNITS
MOJAVE, CALIFORNIA
SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE
13

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4.0 DISCUSSION

Analysis of the data collected indicate similarities in general geologic conditions between the Ranegras Plain and Mojave sites with an important difference in hydrologic setting. The similarities include:

- o Alluvial fan deposits are the predominant surficial geologic units with younger deposits being most abundant.
- o Valleys are generally down-dropped structural blocks bounded by mountain ranges.

Dissimilar features are:

- o The Mojave site consists of a closed basin containing playa deposits. Ranegras Plain is an open basin with drainage through ~~the~~ Bouse Wash to the Colorado River.
- o The Mojave site shows evidence for active faulting and uplift, including displaced Quaternary deposits; tectonic stability characterizes the Ranegras Plain site.
- o The Mojave site has significant accumulations of unstabilized eolian deposits, whereas, the Ranegras Plain site has low, stabilized dunes of limited extent.
- o Soils range in composition from coarse sandy and gravelly soils at the Mojave site to silty and sandy soils at the Ranegras Plain site.
- o Slopes can be characterized as relatively steep (3 to 6 percent) at the Mojave site due to the active tectonic setting, whereas, gentle alluvial slopes (1 to 2 percent) are most common at the Ranegras Plain site.

Based on regional geologic information, geotechnical conditions at the Ranegras Plain site characterize much of the eastern part of the Sonoran CSP, particularly the area surrounding the site and north of the Gila River. These areas comprise more than 40 percent of the Sonoran CSP. Geotechnical conditions at the Mojave Site are representative of approximately 30 percent of the Sonoran CSP, particularly those areas in California and Nevada. In the remaining 30 percent of the CSP, conditions are transitional and are more accurately described by a combination of conditions present at ea site.

strengths. Except in areas close to mountain fronts, compressional wave velocities range from 1000 to 5000 fps (305 to 1524 mps) up to depths of 150 feet (46 m) below ground surface; velocities in this range indicate good excavatability for vertical shelters by augers, continuous trenches by an MX trencher, and horizontal shelters using conventional equipment. In approximately 20 percent of the area, the excavation walls of vertical shelters may be unstable, requiring slurry or other special techniques of excavation. Approximately five percent of the area may have zones of concentrated cobbles and boulders. In these areas an MX trencher cannot be used and excavations can be accomplished using conventional construction equipment.

Depth to rock is greater than 150 feet (46 m) over approximately 90 percent of the site areas. Depth to ground water is generally greater than 300 feet (92 m) in Ranegras Plain site and greater than 150 feet (46 m) over a major portion of the Mojave site. Therefore, additional expense for excavation of vertical shelters due to hard drilling and ground water will be minimal.

- o Backfill - Subsurface soils are generally suitable for backfill and compaction in trench excavations; minimum compactive effort will be required. Import of backfill material from other parts of the sites will be required for areas of concentrated cobbles and boulders and extensive clay deposits.

5.0 CONSTRUCTION CONSIDERATIONS

For the MX missile system deployment, the three basing mode concepts presently considered are vertical shelter, hybrid trench, and horizontal shelter. The important geotechnical factors for a vertical shelter are primary, secondary, and interconnecting roads, excavation of shelters, and drainage crossings. For the hybrid trench, important geotechnical factors are excavation and backfill, roads (primary, secondary and temporary), drainage crossings, and aggregates for concrete and roads. For the horizontal shelter, roads and drainage crossings are the most important geotechnical factors. A summary of the applicable geotechnical factors is presented in the following paragraphs:

- o Terrain - Surficial slopes are typically less than two percent in the Ranegias Plain site, and range from three to six percent in the Mojave site. These gentle slopes will require little preconstruction grading for roads and trenches. Depths of drainage incision are generally less than three feet (0.9 m), therefore, the need for major drainage structures for roads and trenches will be minimal.
- o Roads - Few roads exist at the sites and a network of roads will be required. Approximately 90 percent of the surficial deposits are coarse-grained soils consisting mainly of silty sands, gravelly sands and sandy gravels. These soils will generally provide good to excellent subgrade materials.
- o Excavation - Most of subsurface soils are dense, weakly to moderately cemented, and have moderately high shear

- o Aggregates and Water - Sufficient quantities of aggregates and water required for roads and concrete are available within and/or adjacent to the sites.

6.0 CONCLUSIONS

In summary, Ranegras Plain and Mojave sites present favorable geotechnical conditions for deployment of any of the three present MX basing mode concepts. Geotechnical conditions from these two sites can be extrapolated to approximately 70 percent of the Sonoran CSP.

APPENDIX A
GENERAL GEOTECHNICAL INFORMATION

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APPENDIX A

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GLOSSARY OF TERMS

ACTIVITY NUMBER - A designation composed of the valley abbreviation followed by the activity type and a unique number; may also be used to designate a particular location in a valley.

AEROMAGNETIC DATA - Magnetometer observations made from an airplane.

ALLUVIAL BASIN - A lowland area, generally between uplifted mountain blocks, filled with alluvial deposits.

ALLUVIAL FAN - A low, outspread, relatively flat to gently sloping mass of alluvium, shaped like an open fan or a segment of a cone, deposited by a stream (especially in a semiarid region) at the place where it issues from a narrow mountain valley upon a plain or broad valley. It is steepest near the mouth of the valley where its apex points upstream, and it slopes gently and convexly outward with gradually decreasing gradient.

ALLUVIAL FAN DEPOSITS - Alluvium deposited by a stream or other body of running water as a sorted or semisorted sediment in the form of a cone or fan at the base of a mountain slope.

ALLUVIAL PLAIN - A level or gently sloping tract or a slightly undulating land surface produced by extensive deposition of alluvium, usually adjacent to a river that periodically overflows its banks; it may be situated on a flood plain, a delta, or an alluvial fan.

ALLUVIUM - A general term for unconsolidated clay, silt, sand, gravel, and boulders deposited during relatively recent geologic time by a stream or other body of running water as a sorted or semisorted sediment in the bed of a stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.

ANOMALY - 1) A deviation from uniformity in physical properties; especially a deviation from uniformity in physical properties of exploration interest. 2) A portion of a geophysical survey which is different in appearance from the survey in general.

AQUIFER - A permeable saturated zone below the earth's surface capable of conducting and yielding water as to a well.

GLOSSARY OF TERMS (Cont.)

ARKOSIC SANDSTONE - A sandstone with considerable feldspar, such as one containing minerals from coarse-grained quartzo-feldspathic rocks (granites, granodiorites, medium or high-grade schists) or from older, highly feldspathic sedimentary rocks; specifically a sandstone containing more than 25% feldspar and less than 20% matrix material of clay, sericite, and chlorite.

ARRIVAL - An event; the appearance of seismic energy on a seismic record; a line-up of coherent energy signifying the arrival of a new wave train.

ATTERBERG LIMITS - A general term applied to the various tests used to determine the various states of consistency of fine grained soils. The four states of consistency are solid, semisolid, plastic, and liquid.

Liquid limit (LL) - The water content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil (ASTM D423-66).

Plastic limit (PL) - The water content corresponding to an arbitrary limit between the plastic and the semisolid states of consistency of a soil (ASTM D424-59).

Plasticity index (PI) - Numerical difference between the liquid limit and the plastic limit.

BASIN-FILL MATERIAL/BASIN-FILL DEPOSITS - Heterogenous detrital material deposited in a sedimentary basin.

BEDROCK - Rock with a seismic p-wave velocity of 7000 ft (2333 m) per second or more.

BOUGUER ANOMALY - The residual value obtained after latitude, elevation and terrain corrections have been applied to gravity data.

BOULDER FIELD - Five or more rocks, each with diameters of 6 ft or more occurring within an acre.

BULK SAMPLE - A disturbed soil sample (bag sample) obtained from cuttings brought to the ground surface by a drill rig auger or obtained from the walls of a trench excavation.

c - Cohesion (Shear strength of a soil not related to inter-particle friction).

CALICHE - Gravel, sand or other material cemented principally by calcium carbonate.

GLOSSARY OF TERMS (Cont.)

- CALIFORNIA BEARING RATIO (CBR) - A test performed on a specifically prepared soil sample which is useful in the design of road pavement to be supported by the soil tested (ASTM D1833-73). The load is applied on the penetration piston which is penetrated into the soil sample at a constant penetration rate. The bearing ratio reported for the soil is normally the one at 0.1 inches (2.5 mm) penetration.
- CANDIDATE - One of some group of regions, areas or sites being considered for MX deployment. Removal of candidate from a specifically named region, area or site term indicates selection by SAMSO/MNND.
- CANDIDATE DEPLOYMENT AREA (CDA) - An area encompassing between 500 and 1000 square nautical miles of potentially suitable land with either naturally or artificially defined boundaries designated for convenience of study, discussion and data depiction. The candidate deployment area could be composed of two to four parcels and should have a specific place name description.
- CANDIDATE DEPLOYMENT PARCEL (CDP) - An area of 150 to 500 square nautical miles potentially suitable for MX siting which, when aggregated with others, forms a Candidate Deployment Area. Each parcel should have a specific geographic description. (In the Basin and Range Physiographic province a parcel may correspond to a geographic valley and in Texas to some agri-economic unit.)
- CANDIDATE DEPLOYMENT SITE (CDS) - A non-specific (i.e. not finally approved) site proposed for some element of the MX system within a chosen deployment area (i.e. trench or shelter site).
- CANDIDATE SITING PROVINCE (CSP) - An area potentially suitable for deployment of the MX system generally encompassing more than 6000 square nautical miles which, in a broad sense, is homogeneous with respect to most of the important characteristics governing siting of a total MX system.
- CANDIDATE SITING REGION (CSR) - Potentially suitable area between 4000 and 6000 square nautical miles within one, or encompassing portions of more than one, candidate siting province which allows for full MX deployment.

GLOSSARY OF TERMS (Cont.)

- CAPABLE (fault) - Movement at or near the surface at least once in the past 35,000 years, and/or more than once in the past 500,000 years, (Nuclear Regulatory Commission).
- CAPROCK - A resistant, moderately to strongly cemented caliche layer forming a "cap" over less resistant layers.
- CD TRIAXIAL SHEAR-A type of test to measure the shear strength of an undisturbed soil sample
- CLOSED BASIN - A catchment area draining to some depression or lake within its area, from which water escapes only by evaporation.
- COARSE-GRAINED - A term which applies to a soil of which more than one-half of the soil particles, by weight, are larger than 0.075 mm in diameter (passing the No. 200 U.S. size).
- COARSER-GRAINED - A term applied to alluvial fan deposits which are predominantly composed of material larger than 3 inches (76 mm) in diameter.
- COLLUVIAL DEPOSITS - A general term applied to any loose, heterogenous, and incoherent mass of soil material or rock fragments deposited chiefly by dislodgement and downslope transport of the material under the direct application of gravitational body stresses. Material is usually found at the base of a steep slope or cliff.
- COMPACTION TEST - A type of test to determine the relationship between the moisture content and density of a soil sample which is prepared in compacted layers at various water contents (ASTM D1557-70).
- COMPRESSIBILITY-Property of a soil pertaining to its susceptibility to decrease in volume when subjected to load.
- COMPRESSIONAL WAVE -An elastic body wave in which particle motion is in the direction of propagation; the type of seismic wave assumed in conventional seismic exploration. Also called P-wave, dilatational wave, and longitudinal wave.
- CONSOLIDATION TEST - A type of test to determine the compressibility of a soil sample. The sample is enclosed in the consolidometer which is then placed in the loading device. The load is applied in increments at certain time intervals and the change in thickness is recorded.

GLOSSARY OF TERMS (Cont.)

- CONTERMINOUS UNITED STATES - The contiguous 48 states.
- CORE SAMPLE - A cylindrical sample obtained with a rotating core barrel with a cutting bit at its lower end. Core samples are obtained from indurated deposits and in rock.
- DEBRIS FLOW - A high-density flow of mud containing abundant coarse-grained materials (boulders, cobbles, gravel, sand) that frequently result from an unusually heavy rain.
- DEGREE OF SATURATION - Ratio of volume of water in soil to total volume of voids.
- DETECTOR - See GEOPHONE.
- DIRECT SHEAR TEST - A type of test to measure the shear strength of a soil sample where the sample is forced to fail on a predetermined plane.
- DISSECTION/DISSECTED (alluvial fans) - The cutting of stream channels into the surface of an alluvial fan by the movement (or flow) of water.
- DISTAL - That portion of an alluvial deposit farthest from its point of origin.
- DRY UNIT WEIGHT/DRY DENSITY - Weight per unit volume of the solid particles in a soil mass.
- ELECTRICAL CONDUCTIVITY - Ability of a material to conduct electrical current
- ELECTRICAL RESISTIVITY - Property of a material which resists flow of electrical current
- ENTRENCH - The process whereby a stream erodes downward to form a trench.
- EOLIAN - A term applied to materials which are deposited by wind.
- EPHEMERAL(stream) - A stream in which water flow is discontinuous and of short duration.
- EXTERNAL DRAINAGE - Stream drainage system whose downgradient flow is unrestricted by any topographic impediments.
- EXTRUSIVE (rock) - Igneous rock that has been ejected onto the earth's surface (e.g., lava, basalt, rhyolite, andesite; detrital material, volcanic tuff, pumice).

GLOSSARY OF TERMS (Cont.)

- FAULT** - A plane or zone of rock fracture along which there has been displacement.
- FAULT BLOCK MOUNTAINS** - Mountains that are formed by normal faulting in which the surface crust is divided into structural, partially to entirely fault-bounded blocks of different elevations.
- FINE-GRAINED** - A term which applies to a soil of which more than one-half of the soil particles, by weight, are smaller than 0.075 mm in diameter (passing the No. 200 U.S. size sieve).
- FINER-GRAINED** - A term applied to alluvial fan deposits, which are composed predominantly of material less than 3 inches (76 mm).
- FLOODING/LOW ENERGY FLOW** - Flood waters flowing on a slope of low gradient.
- FLUVIAL DEPOSITS** - Material produced by river action; generally loose, moderately well-graded sands and gravel.
- FORMATION** - A mappable assemblage of rocks characterized by some degree of homogeneity or distinctiveness.
- FREE AIR ANOMALY** - Gravity data which have been corrected for latitude and elevation (free air correction) but not for the density of rock between the datum and the plane of measurement (Bouguer correction).
- FUGRO DRIVE SAMPLE** - A 2.50 inch (6.4 cm) diameter soil sample obtained from a drill hole with a Fugro Drive Sampler. The Fugro drive sampler is a ring-lined barrel sampler containing 12 one-inch (2.54 cm) long brass sample rings. The sampler is advanced into the soil using a drop-hammer.
- GAMMA** - A unit of magnetic-field intensity. A gamma is 10^{-5} oersteds; sometimes expressed (incorrectly) as 10^{-5} gauss with which it is numerically equal.
- GEOMORPHOLOGY** - The study, classification, description, nature, origin, and development of present landforms and their relationships to underlying structures, and of the history of geologic changes as recorded by these surface features.
- GEOPHONE** - The instrument used to transform seismic energy into electrical voltage; a seismometer, jug, or pick-up.

GLOSSARY OF TERMS (Cont.)

GRAIN-SIZE ANALYSIS (GRADATION) - A type of test to determine the distribution of soil particle sizes in a given soil sample. The distribution of particle sizes larger than 0.075mm (retained on the No. 200 sieve) is determined by sieving, while the distribution of the particle sizes smaller than 0.075 mm is determined by a sedimentation process, using a hydrometer.

GRAVEL - Particles of rock that pass a 3-in. (76.2 mm) sieve and retained on a No. 4 (4.75 mm) sieve

GRAVITY - The force of attraction between bodies because of their mass. Usually measured as the acceleration of gravity.

GRAVITY GRADIENT - The partial derivative of the acceleration of gravity with respect to distance in a particular direction, for which purpose the acceleration of gravity is considered as a scalar.

INTERIOR DRAINAGE - Stream drainage system that flows into a closed topographic low (basin).

INTRUSIVE (rock) - A rock formed by the process of emplacement of magma (liquid rock) in pre-existing rock. (e.g. granite, granodiorite, quartz monzonite).

LACUSTRINE DEPOSITS - Materials deposited in lake environment.

LINE - A linear array of observation points, such as a seismic line.

LIQUID LIMIT - See ATTERBERG LIMITS.

LOESS - A wind blown deposit predominantly silt or silty clay or clayey silt.

LOW ENERGY FLOW - See FLOODING.

MAGNETIC INTENSITY - A vector quantity measuring magnetic field strength. The unit of magnetic intensity commonly used in geophysical exploration is the gamma (see GAMMA).

MANTLED PLAYA - A playa surface or a portion of the surface that is covered with younger geologic material such as windblown sand, or alluvium.

MILLIGAL - A unit of acceleration used with gravity measurements; 1 milligal = 10^{-5} m/sec.². Abbreviated mgal.

GLOSSARY OF TERMS (Cont.)

MOISTURE CONTENT - The ratio, expressed as a percentage, of the weight of water contained in a soil sample to the oven-dry weight of the sample.

N VALUE - Penetration resistance, number of blows required to drive the standard split spoon sampler for the second and third six inches (0.15 m) with a 140 pound (63.5 kg) hammer falling 30 inches (0.76 m) (ASTM D1586-67).

OPTIMUM MOISTURE CONTENT - Moisture content at which a soil can be compacted to a maximum dry unit weight by a given compactive effort

OVERBANK FLOODING - A large flow of water that overflows the sides of A stream channel.

O - Angle of internal friction

PATINA - A dark coating or thin outer layer produced on the surface of a rock or other material by weathering after long exposure (e.g., desert varnish).

PAVEMENT/DESERT PAVEMENT - When loose material containing pebble-sized or larger rocks is exposed to rainfall and wind action the finer dust and sand are blown or washed away and the pebbles gradually accumulate on the surface, forming a mosaic which protects the underlying finer material from wind attack. Pavement can also develop in finer-grained materials. In this case the armored surface is formed by dissolution and cementation of the grains involved.

PEGMATITE DIKE - A coarse grained igneous rock of granitic composition that forms as a tabular intrusion that cuts across the planar structures of the surrounding rock.

P-WAVE - See COMPRESSIONAL WAVE.

PERIMETER SEISMIC REFRACTION SURVEY - Shallow seismic refraction measurements made around the perimeter of a valley.

PERMEABLE - The ability of liquid to pass through soil and/or rock material.

PICK-UP - See GEOPHONE.

GLOSSARY OF TERMS (Cont.)

PITCHER TUBE SAMPLE - An undisturbed, 2.87 inch (73 mm) diameter soil sample obtained from a drill hole with a Pitcher tube sampler. The primary components of this sampler are an outer rotating core barrel with a bit and an inner stationary, spring-loaded, thin-wall sampling tube which leads or trails the outer barrel drilling bit, depending upon the hardness of the material being penetrated.

PLASTIC LIMIT - See ATTERBERG LIMITS.

PLASTICITY INDEX - See ATTERBERG LIMITS.

PLAYA/PLAYA DEPOSITS - A term used in the southwest U.S. for a dried-up, flat-floored area composed of thin, evenly stratified sheets of fine clay, silt, or sand, and representing the lowest part of a shallow, completely closed or undrained, desert lake basin in which water accumulates and is quickly evaporated, usually leaving deposits of soluble salts.

PONDING (of water) - The accumulating of water in a topographic depression.

PRIME - Modifier used to indicate the highest ranking province, region, area, or site. If not an interdisciplinary ranking, then a qualifier should be used such as "prime" geotechnical candidate siting area".

PROXIMAL - That portion of an alluvial deposit nearest to its point of origin.

REGIONAL - The general attitude or configuration disregarding features smaller than a given size. The regional gravity is the gravity field produced by large-scale variations ignoring anomalies of smaller size. See residualize.

RELATIVE AGE - The relationship in age (oldest to youngest) between geologic units without specific regard to number of years.

RESIDUAL - What is left after a regional field has been removed, as in gravity or magnetic analysis. See RESIDUALIZE.

GLOSSARY OF TERMS (Cont.)

RESIDUALIZE - The process of separating a graphically depicted curve or a surface into its low-frequency parts (called the regional) and its high-frequency parts (called the residual). Residualizing is an attempt to sort out of the total field those anomalies which result from local structure; that is, to fine local anomalies by subtracting gross (regional) effects.

ROCK UNITS - Distinct rock masses with different characteristics (e.g., igneous, metamorphic, sedimentary).

S-WAVE - See SHEAR WAVE.

SAND - Soil passing through No. 4 (4.75 mm) sieve and retained on No. 200 (0.075 mm) sieve

SAND DUNE - A low ridge or hill consisting of loose sand deposited by the wind, found in various desert and coastal regions and generally where there is abundant surface sand.

SEISMIC - Having to do with elastic waves. Energy may be transmitted through the body of an elastic solid as P-waves (compressional waves) or S-waves (shear waves).

SEISMIC REFRACTION DATA: deep/shallow - Data derived from a type of seismic shooting based on the measurement of seismic energy as a function of time after the shot and of distance from the shot, by determining the arrival times of seismic waves which have travelled nearly parallel to the bedding in high-velocity layers, in order to map the depth to such layers.

SEISMOGRAM - A seismic record.

SEISMOMETER - See GEOPHONE.

SHEAR WAVE - A body wave in which the particle motion is perpendicular to the direction of propagation. Also called S-Wave or transverse wave.

SHEET FLOW - A process in which storm-borne water spreads as a thin, continuous veneer (sheet) over a large area.

T SAND - A blanket deposit of sand which accumulates in shallow depressions or against rock outcrops, but does not have characteristic dune form.

A source of seismic energy; e.g., the detonation of a mine.

GLOSSARY OF TERMS (Cont.)

- SHOT POINT - The location of any source of seismic energy; e.g., the location where an explosive charge is detonated in one hole or in a pattern of holes to generate seismic energy. Abbreviated SP.
- SILT AND CLAY - Fine-grained soil passing through No. 200 (0.075 mm) sieve.
- SITE - Location of some specific activity or reference point. The term should always be modified to a precise meaning or be clearly understood from the context of the discussion.
- SPECIFIC GRAVITY - The ratio of the weight in air of a given volume of soil solids at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature.
- SPLIT SPOON SAMPLE - A disturbed sample obtained with a split spoon sampler with an outside diameter of 2.0 inches (5.1 cm). The sample consists of a split barrel which is driven into the soil using a drop-hammer.
- SPREAD - The layout of geophone groups from which data from a single shot are recorded simultaneously. Spreads containing twenty-four geophones have been used in Fugro's seismic refraction surveys.
- STREAM CHANNEL DEPOSITS - Materials (clay, silt, sand, gravel, cobbles, boulders) which have been deposited in a stream channel.
- STREAM TERRACE DEPOSITS - Stream channel deposits no longer part of an active stream system, generally loose, moderately well graded sand and gravel.
- SURFICIAL DEPOSIT - Unconsolidated residual and alluvial deposits occurring on or near the earth's surface.
- TRANSITORY - A poorly defined, shallow ephemeral stream across an alluvial fan surface, the position of which is temporary and tends to shift frequently.
- UNCONFINED COMPRESSION - A type of test to measure the compressive strength of an undisturbed soil sample.
- UNIFIED SOIL CLASSIFICATION SYSTEM (USCS) - A system which determines soil classification on the basis of grain-size distribution and Atterberg Limits. (See page A-17).

GLOSSARY OF TERMS (Cont.)

VALLEY SEISMIC REFRACTION SURVEY - Deep seismic refraction measurements made near the middle of a valley to determine seismic wave propagation velocities and thickness of basin fill.

VELOCITY - Refers to the propagation rate of a seismic wave without implying any direction. Velocity is a property of the medium and not a vector quantity when used in this sense.

VELOCITY LAYER - A layer of rock or soil with a homogenous seismic velocity.

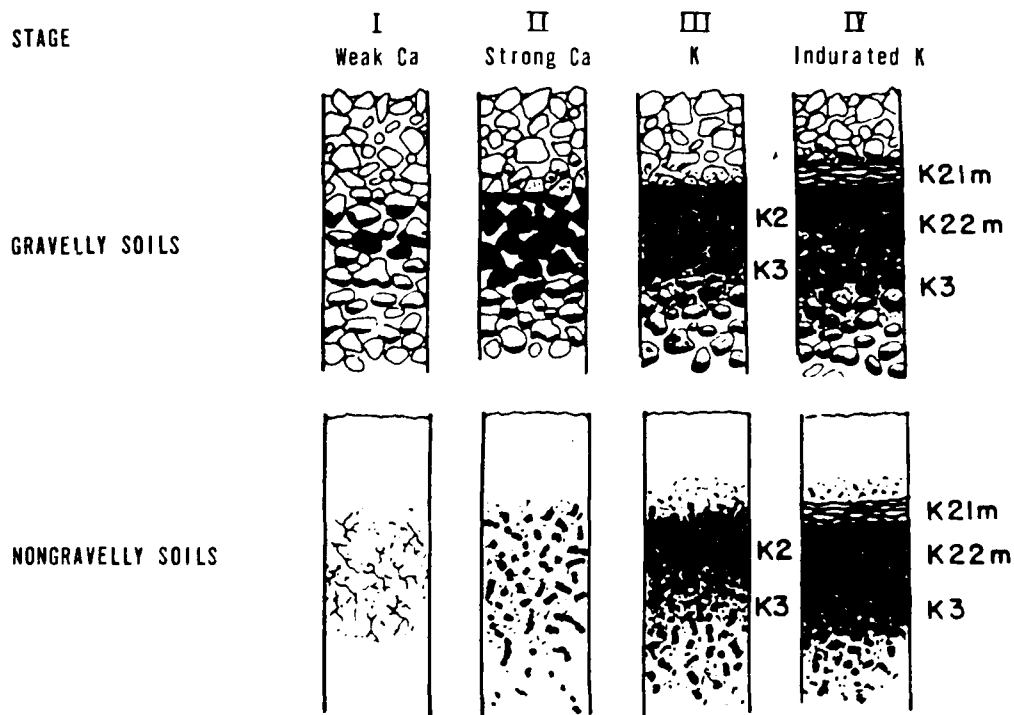
VELOCITY PROFILE - A cross-section showing the distribution of material seismic velocities as a function of depth and its configuration.

WASH SAMPLE - A sample obtained by screening the returned drilling fluid during rotary wash drilling to obtain lithologic information between samples.

Definitions were derived in part from Webster's New Collegiate Dictionary (1972 edition), Glossary of Geology (American Geological Institute, 1972), Encyclopedic Dictionary of Exploration Geophysics (Sheriff, 1973), and 1976 Annual Book of ASTM Standards.

DIAGNOSTIC CARBONATE MORPHOLOGY

STAGE	GRAVELLY SOILS	NONGRAVELLY SOILS
I	Thin, discontinuous pebble coatings	Few filaments or faint coatings
II	Continuous pebble coatings, some interpebble fillings	Few to abundant nodules, flakes, filaments
III	Many interpebble fillings	Many nodules and internodular fillings
IV	Laminar horizon overlying plugged horizon	Laminar horizon overlying plugged horizon



Stages of development of a caliche profile with time. Stage I represents incipient carbonate accumulation, followed by continuous build-up of carbonate until, in Stage IV, the soil is completely plugged.

SUMMARY OF CALICHE DEVELOPMENT

Reference: Gile, L. H., Peterson, F. F., and Grossman, R. B., 1965.
The K horizon, A master horizon of carbonate accumulation; Soil Science, v. 99, p. 74-82

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSU

FIGURE
A-1

UGRO NATIONAL, INC.

(1)
AREI
SYMBOLS

MX (2)
GEOLOGIC
UNITS

NON-ROCK UNITS

(1)
AREI
SYMBOLS

MX
GEOLOGIC
UNITS

Au, Ast	Au	Non-rock Deposits (undifferentiated); fine- to coarse-grained materials deposited by alluvial, fluvial, eolian, lacustrine, gravity or glacial processes.		
Aal	A1	Fluvial Deposits; predominantly composed of poorly- to well-graded sand and gravel with lesser amounts of silt- and boulder-sized material. The unit predominantly consists of recent water-laid deposits occupying present drainages and flood plains. - Older Fluvial Deposits (A1o) are generally thicker, more extensive units deposited in ancestral fluvial systems. - Alluvial Outwash Deposits (A1w) consist of mixed, geomorphically nondescript alluvial and fluvial deposits covering large, relatively flat, river and playa basins.	gr Vu Vb	I
At	A2	Terrace Deposits; predominantly composed of moderately to well graded, clay- to gravel-sized material. Principally elevated terraces bordering modern streams (A2s) and lakes playas (A2l).	Su	S
	A3	Eolian Deposits; predominantly composed of poorly graded sand-sized material deposited by wind action. Deposits may consist of mixed sand, silt, and clay (A3u), or be differentiated on the basis of predominant grain size and landform. A3s d - Predominantly fine sand-sized material deposited in sheets (A3s) or dunes (A3d). A3l - Loess composed predominantly of silt-sized material with lesser amounts of clay and fine sand. A3f - Predominantly clay-sized material with lesser amounts of silt and fine sand.	Qtz Psa, Pm, Ph, Cau, Ls, Py, Par	
	A4	Lacustrine, Estuarine, and Playa Deposits; predominantly composed of poorly graded clay, silt, and fine sand deposited in bodies of standing water. Older lacustrine, estuarine, and playa deposits (A4o) are thicker, more extensive units occupying ancestral lake basins.	Qtz, gn	M
Aaf	A5	Alluvial Fan Deposits; predominantly composed of well graded sand and gravel with varying amounts of silt-, cobble-, and boulder-sized material. Deposited principally by distributary channels adjacent to mountain fronts. Relative ages are indicated by o - older, i - intermediate, or y - younger.		C
	A6	Pediment, Pediment Deposits, and Areas of Shallow Rock; planated bedrock shelf or near surface rock generally overlain by a thin mantle of sand- to boulder-sized residual or alluvial material.		
	A7	Colluvial Deposits; predominantly composed of moderately- to well-graded sand and gravel with varying amounts of silt-, cobble-, and boulder-sized material. Deposited locally by gravity and water adjacent to steep gradients.		

NOTES: (1) AREI symbols were developed for use in the Aggregate Resources Evaluation Investigation (See Section 5.1 and Drawings 5.1A through 5.1C)

(2) MX Geologic units were used for Methodology, Screening, and Characterization studies.

(1) AREAL
SYMBOLS

MX (2)
GEOLOGIC
UNITS

ROCK UNITS

Shown in regions where rock is exposed; the areally predominant (greater than 70 percent) rock type is indicated. In those areas where two rock types occur the predominant rock type is shown followed by the subordinate rock type (e.g. S2MP I4T).

I IGNEOUS (UNDIFFERENTIATED). Rocks formed by solidification of a molten or partially molten mass.

- gr I1 Intrusive - Typically crystalline, formed by the solidification of molten material below the surface (e.g., granite, syenite, diorite).
- Yu I2 Extrusive (undifferentiated). Formed by solidification of molten material at or near the surface.
- Yb I3 Extrusive (flows). Extrusive rocks formed by solidification of lava (e.g. basalt, dacite) I3 denotes young basaltic flows which may be interbedded with basaltic materials.
- I4 Extrusive (volcaniclastic). Formed by accumulation, welding and or cementation of deposits of volcanic ejecta (e.g. tuff, agglomerate, lapilli).

Su S SEDIMENTARY (UNDIFFERENTIATED). Coarse- to fine-grained materials that exhibit some degree of cementation and were deposited by water, wind, gravity, or evaporation.

- Qtz S1 Sandstone. Composed predominantly of sand-sized particles.
- Psa, Pm, S2 Limestone and Dolomite. Composed predominantly of carbonate material.
- Ph, Cau, S3 Shale. Composed predominantly of clay- and silt-sized particles
- Ls, Py, (e.g. shale, siltstone, mudstone).
- Par S4 Evaporites. Sediments deposited from solution as a result of evaporation (e.g. gypsum, anhydrite, halite).
- S5 Clastics. Undifferentiated deposits composed of silt- to boulder-sized material. May be angular to rounded.

Qtz, gn M METAMORPHIC (UNDIFFERENTIATED). Rocks formed through alteration of igneous or sedimentary rock material by pressure, heat, or chemical changes below the weathered zone (e.g. gneiss, schist, slate, marble, quartzite).

C ROCK COMPLEXES. Indicated where no areally predominant (greater than 70 percent) rock type is present.

USEAGE

Modifying letter (r) indicates concentrations of resistant secondary carbonate (caliche), silicious, ferruginous and or gypsiferous material, e.g. A5ir.

A3s, A5y - Mixed non-rock units; most areally extensive unit is listed first.

A5y(A5i) - Parenthetic unit underlies thin veneer of overlying mapped unit.

S5to - Established formations may have a supplemental letter added to distinguish formal designation (e.g. Tertiary Ogallala Fm.).

EXPLANATION OF GEOLOGIC UNITS

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSQ

TABLE
A-1

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Major Divisions		Group Symbols	Typical Names	Field Identification Procedures (Excluding particles larger than 3 inches and having fractions on estimated weights)	Information Required for Describing Soils
1	2	3	4	5	6
More than half of material is larger than No. 200 sieve size. (Coarse-grained Soils)	Gravels More than half of coarse fraction is larger than No. 4 sieve size. (For visual classification, the 1/4 in. size may be used as equivalent to the No. 4 sieve size.)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics.
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.	
Sands More than half of coarse fraction is smaller than No. 4 sieve size. (For visual classification, the 1/4 in. size may be used as equivalent to the No. 4 sieve size.)	Gravels More than half of coarse fraction is larger than No. 4 sieve size. (For visual classification, the 1/4 in. size may be used as equivalent to the No. 4 sieve size.)	GM	Silty gravels, gravel-sand-silt mixtures.	Nonplastic fines or fines with low plasticity. (For identification procedures see M.L. below)	Give typical name; indicate approximate percentages of sand and gravel, max. size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses. Example: Silty sand, gravelly; about 20% hard, angular, gravel particles 1/2-in. maximum size; rounded and sub-angular sand grains coarse to fine; about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM).
		GC	Clayey gravels, gravel-sand-clay mixtures.	Plastic fines (for identification procedures see C.L. below).	
Sands More than half of coarse fraction is smaller than No. 4 sieve size. (For visual classification, the 1/4 in. size may be used as equivalent to the No. 4 sieve size.)	Gravels More than half of coarse fraction is larger than No. 4 sieve size. (For visual classification, the 1/4 in. size may be used as equivalent to the No. 4 sieve size.)	SW	Well-graded sands, gravelly sands, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information; and symbol in parentheses. For undisturbed soils and information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions. Example: Clayey silt, brown, slightly plastic, small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess, (ML).
		SP	Poorly-graded sands, gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.	
Fine-grained Soils More than half of material is smaller than No. 200 sieve size. (The No. 200 sieve size is about the smallest particle visible to the naked eye.)	Sands More than half of coarse fraction is smaller than No. 4 sieve size. (For visual classification, the 1/4 in. size may be used as equivalent to the No. 4 sieve size.)	SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity. (For identification procedures see M.L. below)	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information; and symbol in parentheses. For undisturbed soils and information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions. Example: Clayey silt, brown, slightly plastic, small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess, (ML).
		SC	Clayey sands, sand-clay mixtures.	Plastic fines (for identification procedures see C.L. below).	
Highly Organic Soils	Sils and Clays Liquid limit greater than 50 Liquid limit less than 50			Identification Procedures on Fraction Smaller than No. 40 Sieve Size	
Highly Organic Soils	Sils and Clays Liquid limit greater than 50 Liquid limit less than 50	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	Dry Strength (Cracking characteristics)	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information; and symbol in parentheses. For undisturbed soils and information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions. Example: Clayey silt, brown, slightly plastic, small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess, (ML).
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Quick to slow	
Highly Organic Soils	Sils and Clays Liquid limit greater than 50 Liquid limit less than 50	OL	Organic silts and organic silty clays of low plasticity.	Medium to high	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information; and symbol in parentheses. For undisturbed soils and information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions. Example: Clayey silt, brown, slightly plastic, small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess, (ML).
		MP	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	None to slight	
Highly Organic Soils	Sils and Clays Liquid limit greater than 50 Liquid limit less than 50	CH	Inorganic clays of high plasticity, fat clays.	None to very slow	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information; and symbol in parentheses. For undisturbed soils and information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions. Example: Clayey silt, brown, slightly plastic, small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess, (ML).
		OH	Organic clays of medium to high plasticity, organic silts.	Medium to high	
Highly Organic Soils	Sils and Clays Liquid limit greater than 50 Liquid limit less than 50	Pt	Peat and other highly organic soils.	None to very slow	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information; and symbol in parentheses. For undisturbed soils and information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions. Example: Clayey silt, brown, slightly plastic, small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess, (ML).
				Readily identified by color, odor, spongy feel and frequently by fibrous texture.	

UNIFIED SOIL CLASSIFICATION SYSTEM

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0TABLE
A-2

FUGRO NATIONAL, INC.

APPENDIX B

GEOTECHNICAL DATA - RANEGRAS PLAIN SITE

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APPENDIX B

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SUMMARY OF LABORATORY TEST RESULTS

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SUMMARY OF SHEAR STRENGTH TESTS

UNCONFINED COMPRESSION TEST RESULTS	Table B-2
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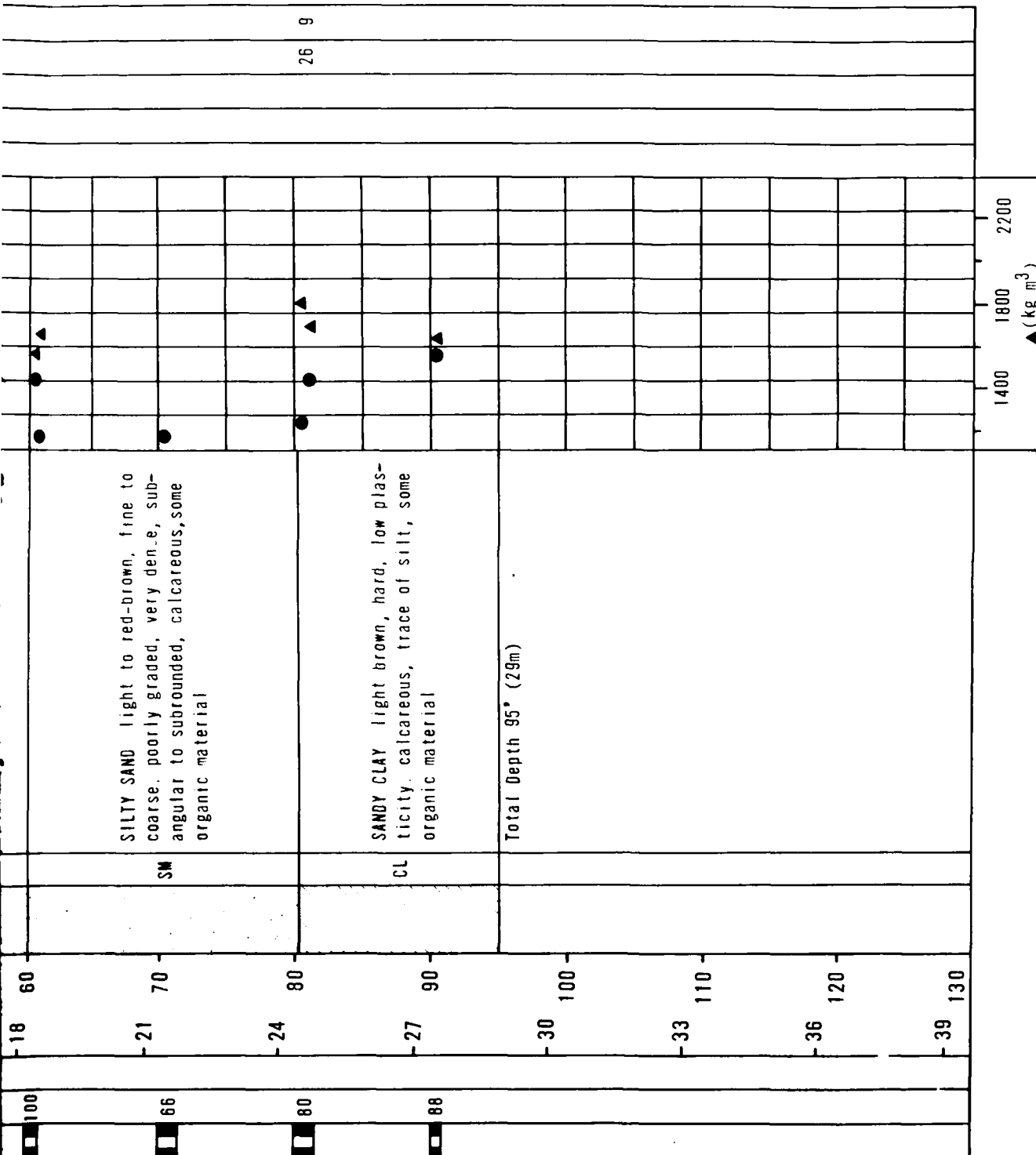
SUMMARY OF CALIFORNIA BEARING RATIO (CBR) TESTS

CALIFORNIA BEARING RATIO (CBR) TEST RESULTS	Table B-5
CALIFORNIA BEARING RATIO (CBR) CURVES	Figure B-7
GRAIN SIZE CURVES, CBR TESTS	Figure B-8

SUMMARY OF CHEMICAL TEST RESULTS

Table B-6

SAMPLE TYPE	% RECOVERY	N VALUE	DEPTH METERS	FEET	LITHOLOGY	USCS	SOIL DESCRIPTION
[Symbol]	80		0	0	SP	CL-ML	SANDY SILT-SANDY CLAY. light brown.
[Symbol]	93				SM	ML	soft to firm. low to medium plasticity.
[Symbol]	53	-3	10		CL-ML	SM	calcareous. layer of medium to coarse sand (0 to 2'). layer of silty sand (5' 5" to 6')
[Symbol]	80				CL	CL	SILT CLAY. light brown. very stiff to hard. low to medium plasticity. calcareous. trace of fine sand.
[Symbol]	73	-6	20		ML	ML	SANDY SILT. light brown very stiff to hard. low plasticity calcareous
[Symbol]	13						
[Symbol]	53	-9	30		SM	SM	SILTY SAND light to red-brown. fine to coarse, poorly graded. very dense. sub-angular to subrounded. calcareous. trace of gravel. weakly cemented caliche
[Symbol]	66						
[Symbol]	77	-12	40				
[Symbol]	46	-15	50		CL	CL	SANDY CLAY light brown hard. medium plasticity. calcareous. weakly cemented caliche.
[Symbol]	100	-18	60				
[Symbol]	66	-21	70		SM	SM	SILTY SAND light to red-brown. fine to coarse. poorly graded, very dense, sub-angular to subrounded, calcareous, some



SAMPLE TYPES

☒ STANDARD PENETRATION TEST

☒ FUGRO DRIVE

LOG
RANEG

MX SITING
 DEPARTMENT OF

BORING DETAILS

ELEVATION : 1382' (421m)
 DATE DRILLED : 14 JANUARY 1978
 DRILLING METHOD : HOLLOW STEM AUGER
 HOLE DIAMETER : 0.075m (3.0in)

Total Depth 95' (29m)

-30 100
-33 110
-36 120
-39 130

1400 1800 2200
▲ (kg m³)

SAMPLE TYPES

□ STANDARD PENETRATION TEST

■ FUGRO DRIVE

▨ BULK

▩ PITCHER TUBE

ENGINEERING PARAMETERS

N - STANDARD PENETRATION TEST (ASTM: D-1586-67)

R - N VALUE GREATER THAN 100 BLOWS/FOOT

▲ - DRY UNIT WEIGHT (ASTM: D-2937-71)

● - MOISTURE CONTENT (ASTM: D-2216-71)

NR - NO RECOVERY

BORING DETAILS

ELEVATION : 1382' (421m)
DATE DRILLED : 14 JANUARY 1978
DRILLING METHOD : HOLLOW STEM AUGER
HOLE DIAMETER : 9" (229mm)
GEOPHYSICAL LOGS : None
CASING INSTALLED : None
WATER LEVEL : Not Encountered

LOG OF BORING RP-8-8
RANEGRAS PLAIN, ARIZONA
SONORAN CSP

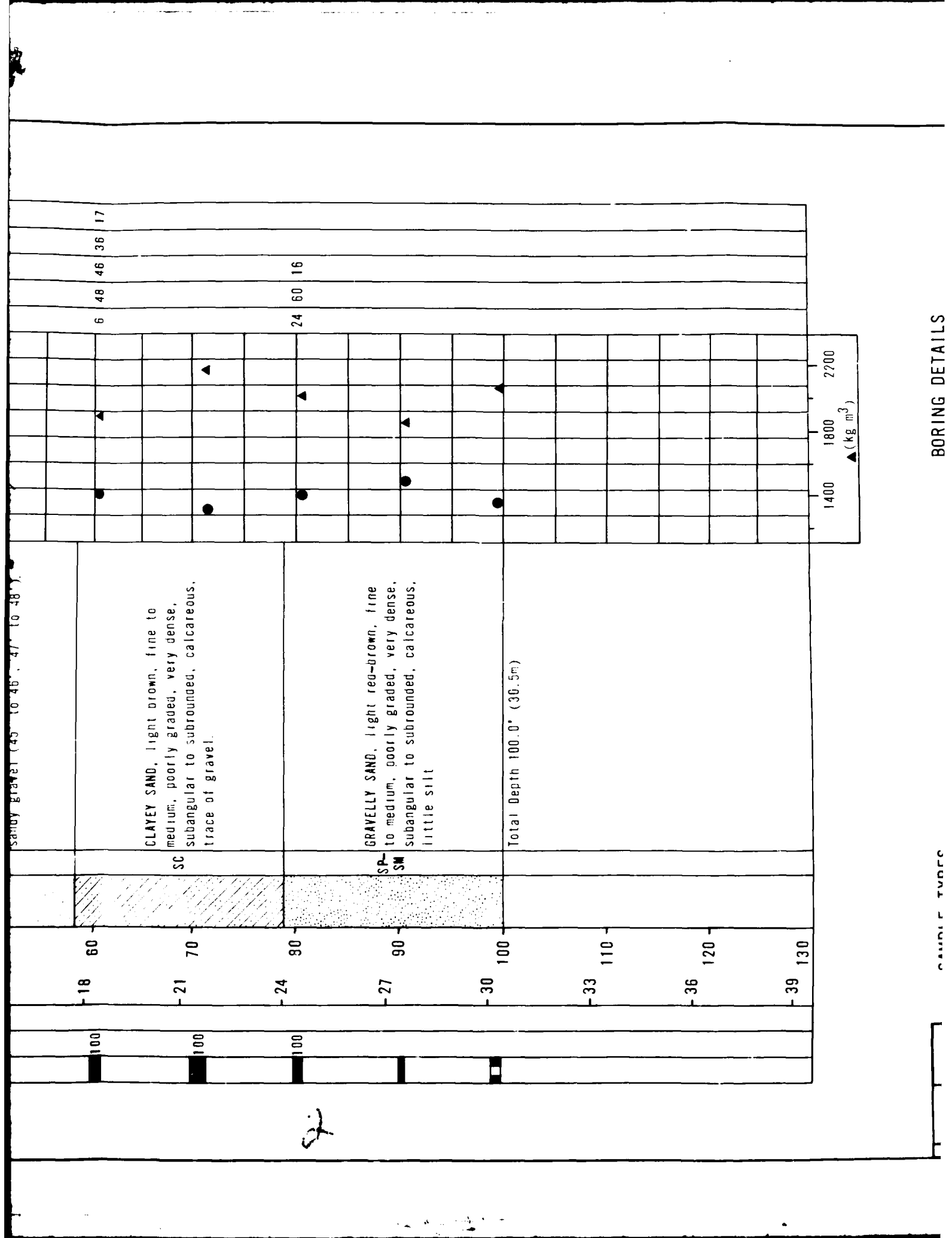
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSU

FIGURE
B-1

FUGRO NATIONAL, INC.

3

SAMPLE TYPE	% RECOVERY	N VALUE	DEPTH METERS FEET	LITHOLOGY	USCS	SOIL DESCRIPTION	▲ (pcf)										SIEVE ANALYSIS			
							80	90	100	110	120	130	140	GR	SA	FI	LL	PI		
			0		SM	SILTY SAND, yellow-brown, fine to medium, poorly graded, loose, calcareous.	●		▲								13	87	30	11
	100																			
	100				CL	SILTY CLAY, brown, very stiff to hard, low plasticity, calcareous, weakly cemented	●		▲					0	13	87				
	100		3		SP-SM	GRAVELLY SAND, brown, fine to coarse, poorly graded, very dense, subangular to subrounded, calcareous, trace of silt, weakly cemented.	●				▲			34	58	8	NP	NP		
	100						●				▲			52	35	13				
	90		6		GM	SANDY GRAVEL, brown, fine to coarse, well graded, very dense, subangular to subrounded, calcareous, little silt, weakly cemented.	●	●		▲				11	75	14				
	100				SM	SILTY SAND, light red-brown, fine to coarse, poorly graded, very dense, calcareous, weakly cemented, trace of gravel.	●		▲					8	78	14				
	100		9				●		▲					2	30	68				
	100				CL	SANDY CLAY, light gray-brown, hard, low plasticity, weakly cemented, caliche nodules	●		▲											
	100		12				●			▲										
	100				SM	SILTY SAND, light brown to light red-brown, fine to coarse, poorly graded, very dense, subangular to subrounded, calcareous, trace of gravel, layers of sandy gravel (45' to 46', 47' to 48')	●		▲											
	100		15																	
	100		18			CLAYEY SAND, light brown, fine to	●		▲					6	48	46	36	17		



BORING DETAILS

CAUTION: TUNNEL

AD-A112 732

FUGRO NATIONAL INC LONG BEACH CA

F/G A/7

MX SITING INVESTIGATION. GEOTECHNICAL SUMMARY. PRIME CHARACTERI--ETC(U)

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UNCLASSIFIED FN-TR-260

NL

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ALL
PAGE 10

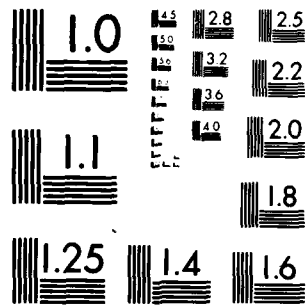
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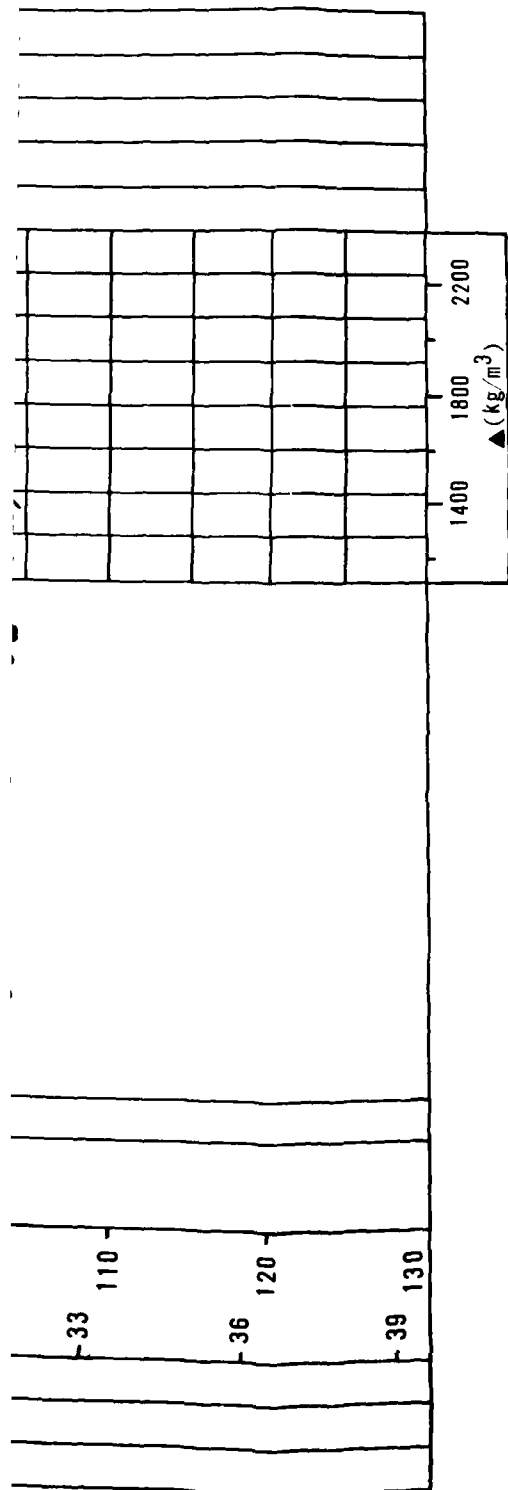
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



SAMPLE TYPES

☐ STANDARD PENETRATION TEST

☐ FUGRO DRIVE

☐ BULK

☐ PITCHER TUBE

ENGINEERING PARAMETERS

- N - STANDARD PENETRATION TEST (ASTM: D-1586-67)
- R - N VALUE GREATER THAN 100 BLOWS/FOOT
- ▲ - DRY UNIT WEIGHT (ASTM: D-2937-71)
- - MOISTURE CONTENT (ASTM: D-2216-71)
- NR - NO RECOVERY

BORING DETAILS

ELEVATION : 1455' (443m)
 DATE DRILLED : 14 JANUARY 1978
 DRILLING METHOD : ROTARY WASH
 HOLE DIAMETER : 4 7/8" (124mm)
 GEOPHYSICAL LOGS : None
 CASING INSTALLED : None
 WATER LEVEL : Not Encountered

LOG OF BORING RP-B-15
 RANERAS PLAIN, ARIZONA
 SONORAN CSP

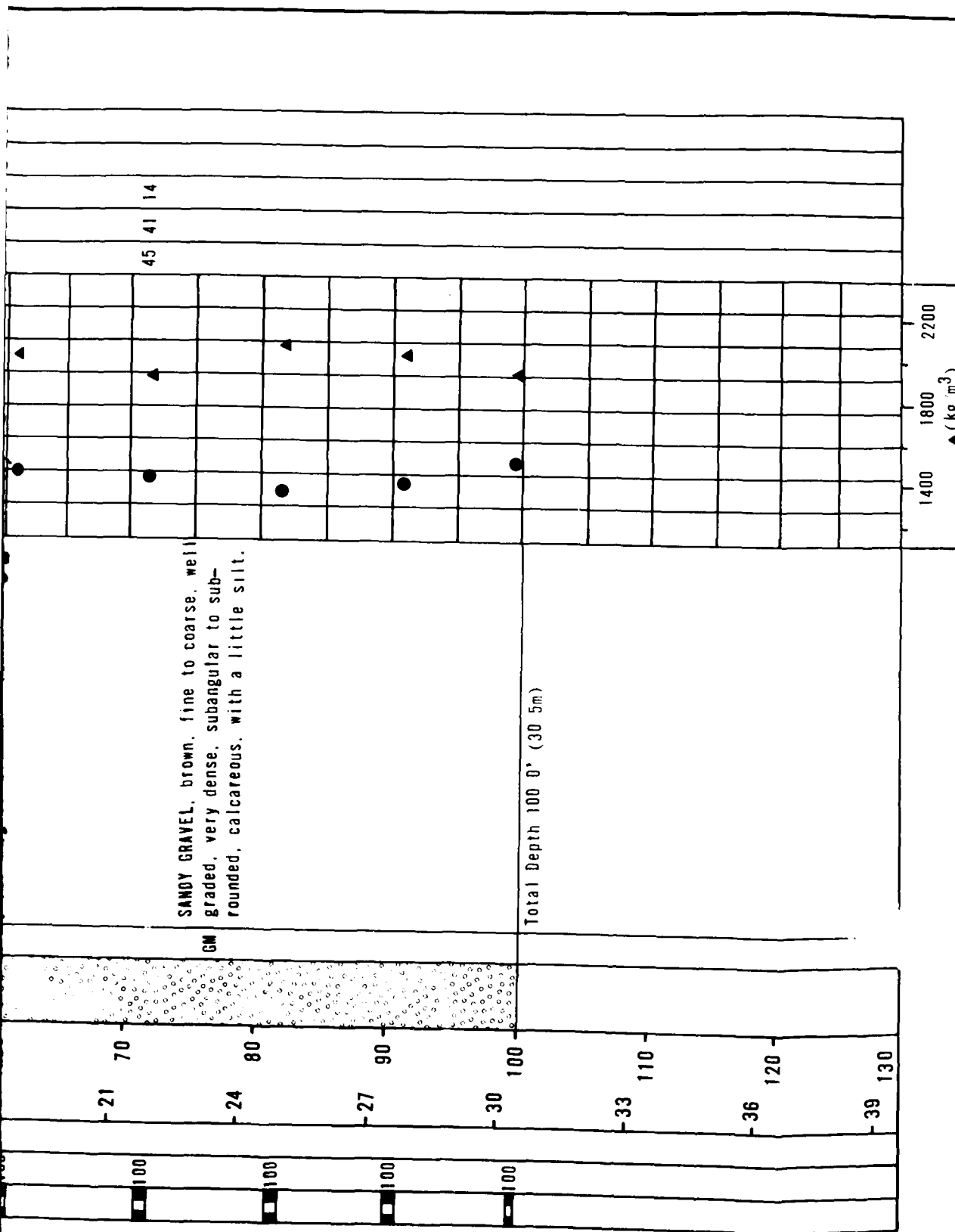
WX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE SAMS

FIGURE
 B-2

FUGRO NATIONAL, INC.

3

SAMPLE TYPE	% RECOVERY	N VALUE	DEPTH METERS FEET	LITHOLOGY	USCS	SOIL DESCRIPTION	▲ (pcf)										SIEVE ANALYSIS			
							80	90	100	110	120	130	140	GR	SA	FI	LL	PI		
	100	0	0		SC	CLAYEY SAND, gray-brown, fine to coarse, poorly graded, medium dense, some gravel.								27	33	40				
	100	-3	10		CL	SANDY CLAY, light brown, hard, low plasticity, calcareous, trace of gravel.								12	38	50	29	10		
	100	-3	10		ML	SANDY SILT, light brown, very stiff, low plasticity, calcareous, trace of gravel, layer of well graded silty sand (10' to 11').								5	47	48	32	8		
	100	-6	20		CL	SANDY CLAY, light brown to brown, very stiff, medium to high plasticity, calcareous, trace of gravel.								0	42	58				
	100	-9	30		SM	SILTY SAND, brown, fine to medium, poorly graded, very dense, subangular to subrounded, calcareous, trace of gravel.								9	40	51	54	27		
	100	-12	40		CL	SILTY CLAY, brown, hard, low to medium plasticity, calcareous, with a little sand.														
	90	-15	50		SP-SM	GRAVELLY SAND, brown, fine to coarse, poorly graded, very dense, subangular to subrounded, calcareous, trace of silt.								25	69	6				
	100	-18	60																	
	100	-21																		

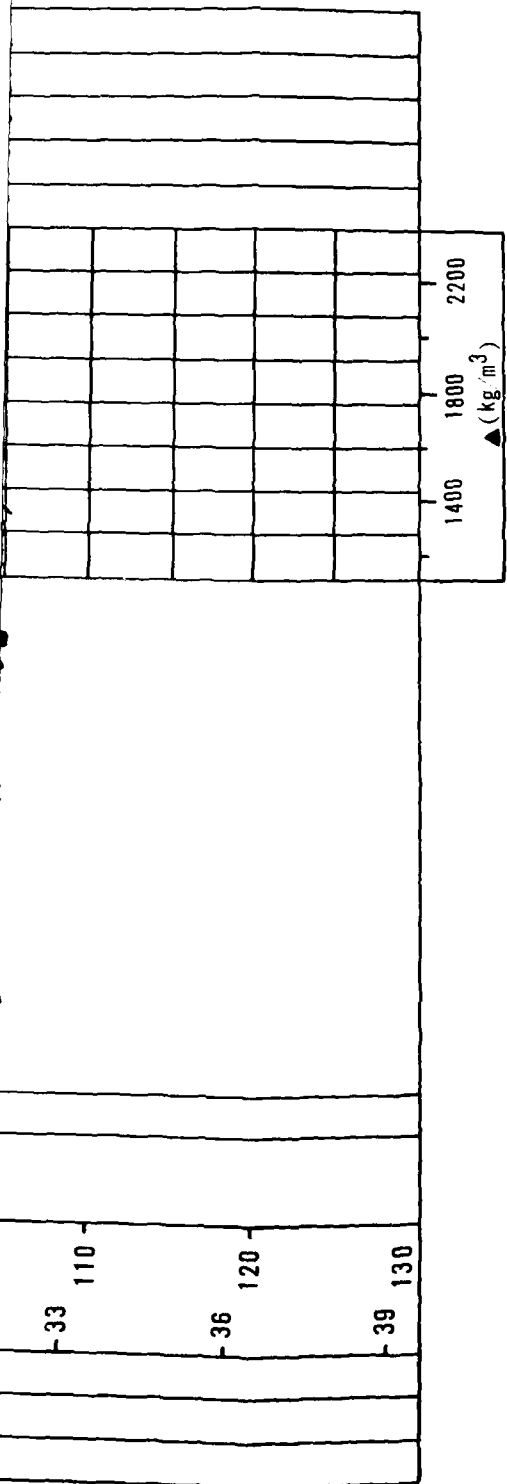


SAMPLE TYPES

- ☐ STANDARD PENETRATION TEST
- ☒ FUGRO DRIVE
- ☐ BULK

BORING DETAILS

ELEVATION : ~1402' (427m)
 DATE DRILLED : 13 JANUARY 1978
 DRILLING METHOD : ROTARY WASH
 HOLE DIAMETER : 4 7 8" (124mm)
 GEOPHYSICAL LOGS : None



SAMPLE TYPES

- ☐ STANDARD PENETRATION TEST
- ☐ FUGRO DRIVE
- ☐ BULK
- ☐ PITCHER TUBE


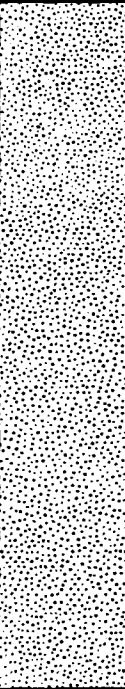
ENGINEERING PARAMETERS

- N - STANDARD PENETRATION TEST (ASTM: D-1586-67)
- R - N VALUE GREATER THAN 100 BLOWS/FOOT
- ▲ - DRY UNIT WEIGHT (ASTM: D-2937-71)
- - MOISTURE CONTENT (ASTM: D-2216-71)
- NR - NO RECOVERY

BORING DETAILS

ELEVATION : ≈1402' (427m)
 DATE DRILLED : 13 JANUARY 1978
 DRILLING METHOD : ROTARY WASH
 HOLE DIAMETER : 4 7/8" (124mm)
 GEOPHYSICAL LOGS : None
 CASING INSTALLED : None
 WATER LEVEL : Not Encountered

LOG OF BORING RP-B-16 RANERAS PLAIN, ARIZONA SONORAN CSP	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE	SAMSQ FIGURE B-3
FUGRO NATIONAL INC.	

BULK SAMPLE	DEPTH		LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS				
	METERS	FEET					GR	SA	FI	LL	PI
	0	0		GW-GM	Loose	SANDY GRAVEL, brown, fine to coarse, well graded, subrounded, calcareous; trace of silt.	52	42	6		
	2			SP	Medium dense	GRAVELLY SAND, light brown, fine to coarse, poorly graded, subrounded, calcareous; trace of silt, weakly cemented; caliche nodules.	26	70	4		
	4										
	6										
	8										
	10										
	12										
	14										
	16										
	18										
	20										
	22					Total Depth 13.0' (4.0m)					

TRENCH DETAILS

SURFACE ELEVATION : 1200' (366m)
 DATE EXCAVATED : 24 January 1978
 SURFACE GEOLOGIC UNIT : A51
 TRENCH LENGTH : 27' (8.2m)
 TRENCH ORIENTATION : N-S

**LOG OF TRENCH RP-T-1
 RANEGRAS PLAIN, ARIZONA
 SONDRAN CSP**

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE - SAMSO

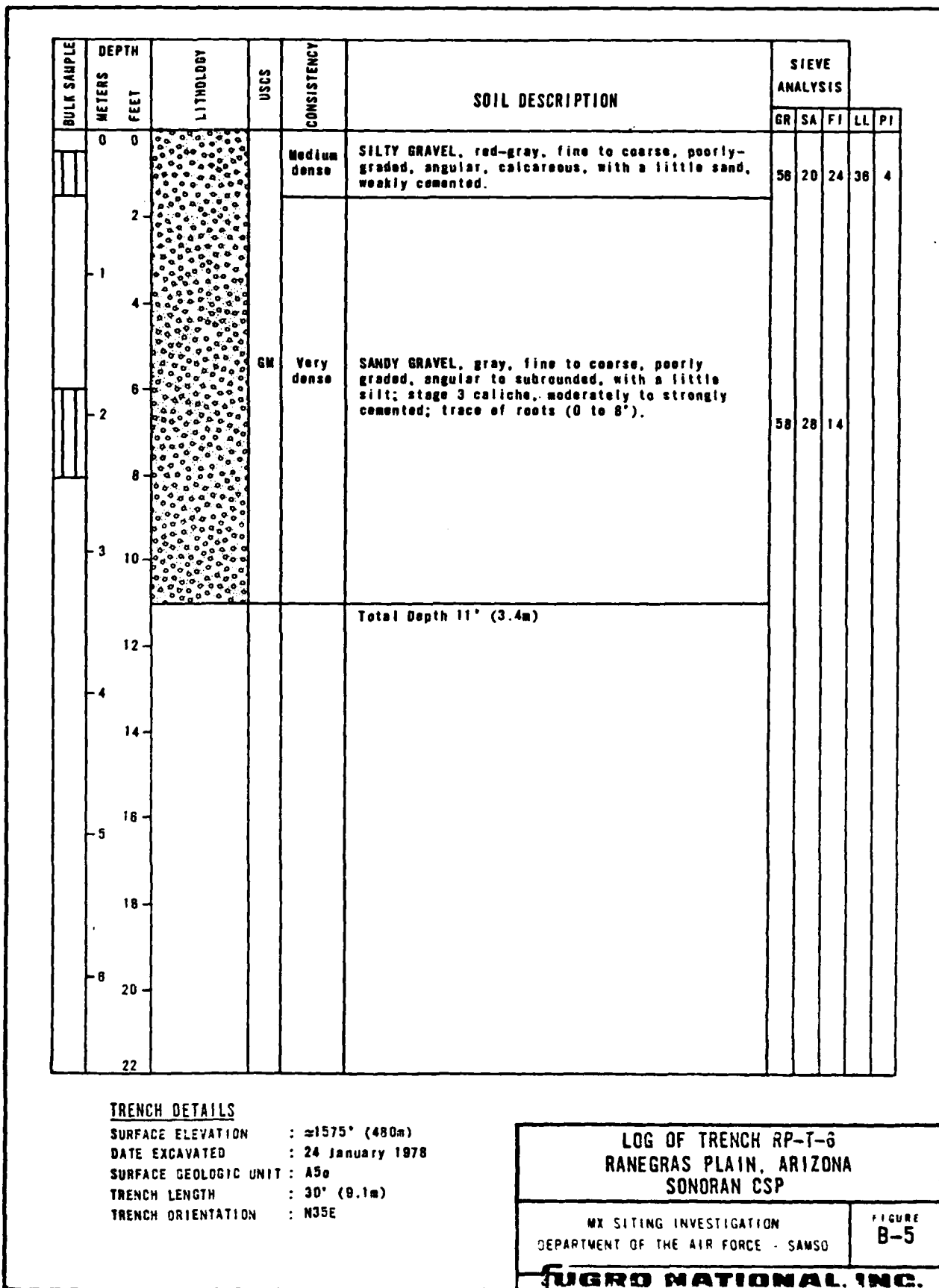
FIGURE
 8-4

UGRO NATIONAL, INC.

APPROVED BY

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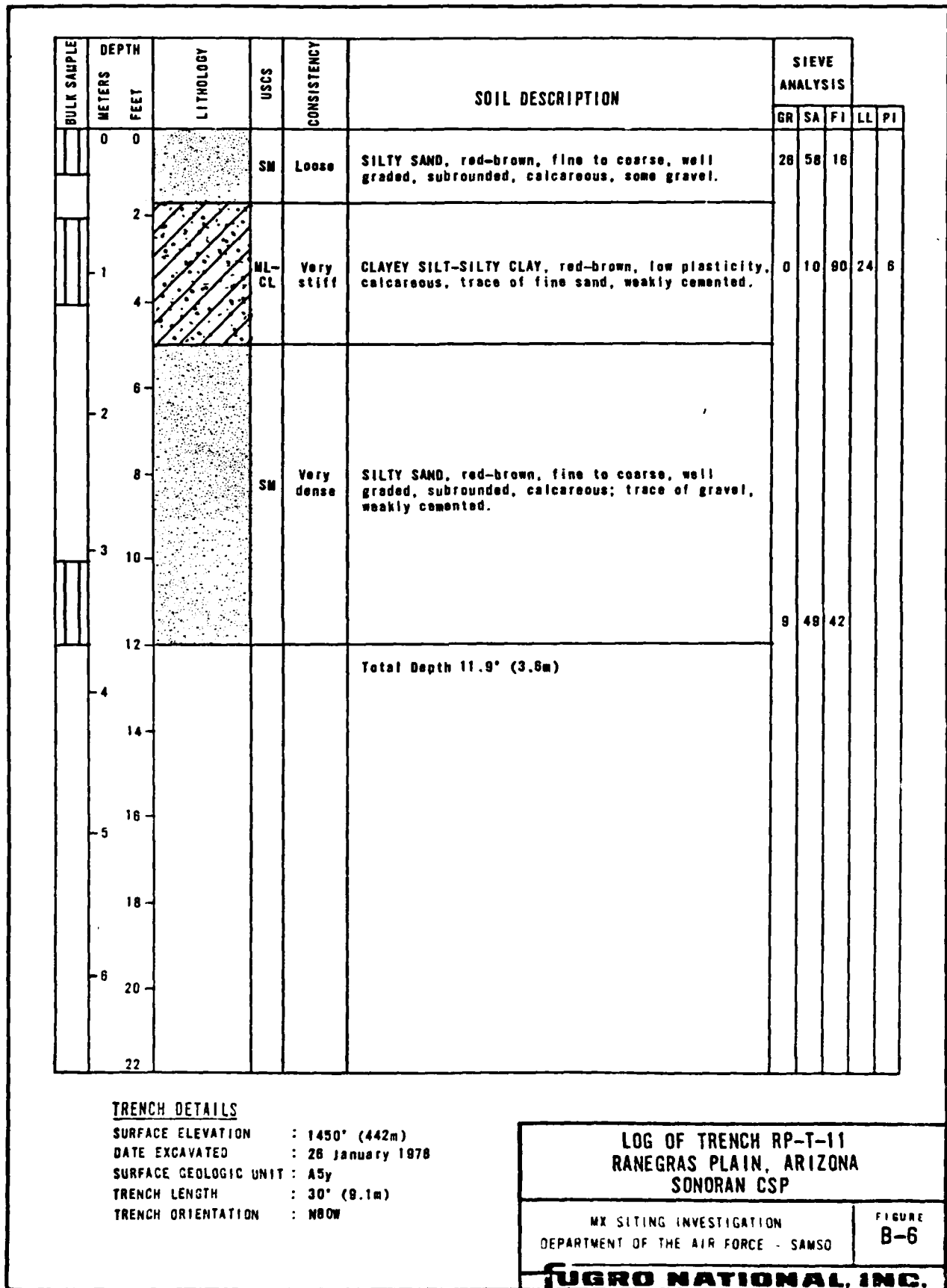
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- (a) Sample types
SS - Standard split spoon
P - Pitcher
D - Fugro Drive
B - Bulk
(b) NP - Not Plastic
- (c) USCS - Unified Soil Classification System
(d) * Indicates that test has been performed and results are included in this report.

STANDARD SIEVE NO					PARTICLE SIZE (mm)	ATTERBERG LIMITS (b)			USCS (c)	IN-SITU				COMPACTED			SPECIFIC GRAVITY OF SOLIDS	TRIAxIAL (d)	UNCONFINED COMPRESSION	DIRECT SHEAR	CONSOLIDATION
AND			SILT OR CLAY		LL	PL	PI	DRY UNIT WEIGHT		MOISTURE CONTENT (%)	SATURATION (%)	VOID RATIO	MAXIMUM DRY DENSITY		OPTIMUM MOISTURE (%)						
40	100	200	.005	.001				(pcf)					(kg/m³)	(pcf)		(kg/m³)					
									CL	101.4	1624	7.4	30.3	0.66					*		
																			*		
																			*		
93		87	24	10	30	19	11		CL												
									SC	112.2	1797	3.5	18.8	0.50							
93		87	26	15					CL												
23	11	8	3	2				NP	SP-SM	123.8	1983	1.1	8.3	0.36					*		
																			*		
																			*		
13	16	13	4	3					GM	126.2	2022	4.6	37.0	0.34					*		
16	14	14	8	6					SC	120.9	1937	10.2	70.2	0.39							
24	16	14	5	5					SM	117.9	1889	6.0	42.5	0.43							
4	76	68	21	12					ML	107.7	1725	9.6	46.1	0.56							
									ML-CL	118.5	1898	8.4	53.9	0.42							
									SP	122.8	1967	7.5	54.4	0.37							
									SP	121.0	1938	6.1	42.2	0.39							
75	57	46	10	6	36	19	17		SC	118.1	1892	9.2	58.2	0.43					*		
									SC	135.5	2171	5.9	65.3	0.24							
25	19	16	6	4					SC	126.6	2028	9.0	73.2	0.33							
									SC	116.1	1860	12.0	72.4	0.45							
									SC	129.3	2071	7.3	65.1	0.30							

2

SUMMARY OF LABORATORY TEST RESULTS BORING RP-B-15 RANGE 145 PLAIN, ARIZONA, SONORAN CSP	
SITO INVESTIGATION DEPARTMENT OF THE AIR FORCE - SAMS0	TABLE B-1
FUGRO NATIONAL, INC.	

3

SUMMARY OF UNCONFINED COMPRESSION
TEST RESULTS
RANEGRAS PLAIN, ARIZONA, SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS0

TABLE
B-2**FUGRO NATIONAL, INC.**[illegible]

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

TABLE
B-3**FUGRO NATIONAL, INC.**

BORING NO.	SAMPLE NO.	SAMPLE INTERVAL		SOIL TYPE	NORMAL STRESS		MAXIMUM SHEAR STRENGTH	
		FEET	METERS		ksf	kN/m ²	ksf	kN/m ²
RP-B-3	D-5	15.2-15.9	4.63-4.85	GP	1.8	86	1.5	72
	D-5	15.2-15.9	4.63-4.85	GP	3.6	172	2.3	110
	D-5	15.2-15.9	4.63-4.85	GP	7.2	345	6.2	297
	D-6	20.2-20.9	6.16-6.37	GP	10	479	7.1	340
	D-6	20.2-20.9	6.16-6.37	GP	2.4	115	2.0	96
	D-6	20.2-20.9	6.16-6.37	GP	4.8	230	5.2	254
RP-B-5	D-2-2	20.5-21.0	6.25-6.40	SC	2.4	115	1.8	86
	D-2-2	20.5-21.0	6.25-6.40	SC	4.8	230	3.8	182
	D-2-2	20.5-21.0	6.25-6.40	SC	9.6	460	5.8	278
RP-B-6	D-4	10.8-11.3	3.29-3.44	CL	1.0	48	1.8	86
	D-4	10.8-11.3	3.29-3.44	CL	2.0	96	4.2	201
	D-4	10.8-11.3	3.29-3.44	CL	4.0	192	5.3	254
RP-B-7	D-4-1	10.0-10.5	3.05-3.20	ML	1.2	57	1.0	48
	D-4-1	10.0-10.5	3.05-3.20	ML	2.4	115	1.6	77
	D-4-1	10.0-10.5	3.05-3.20	ML	4.8	230	3.4	163
RP-B-8	D-3-2	5.5-6.0	1.68-1.83	SM	0.5	24	0.6	29
	D-3-2	5.5-6.0	1.68-1.83	SM	1.0	48	1.1	53
	D-3-2	5.5-6.0	1.68-1.83	SM	2.0	96	2.9	139
	D-4	10.0-10.5	3.29-3.44	SC	1.0	48	1.4	67
	D-4	10.0-10.5	3.29-3.44	SC	2.0	96	1.8	86
	D-4	10.0-10.5	3.29-3.44	SC	4.0	192	4.0	192
RP-B-14	D-5	15.0-15.4	4.57-4.69	CL	3.0	144	2.6	125
	D-5	15.0-15.4	4.57-4.69	CL	2.7	129	1.5	72
RP-B-15	D-1	2.9-3.4	0.88-1.04	CL	1.2	57	1.5	72
	D-1	2.9-3.4	0.88-1.04	CL	0.6	29	3.7	177
	D-1	2.9-3.4	0.88-1.04	CL	0.3	14	2.3	110
	D-5	10.7-11.4	3.26-3.47	SM	1.0	48	1.0	48
	D-5	10.7-11.4	3.26-3.47	SM	2.0	96	1.6	77

SUMMARY OF DIRECT SHEAR TEST RESULTS
PAGE 1 OF 2
RANEGRAS PLAIN, ARIZONA, SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

TABLE
B-4

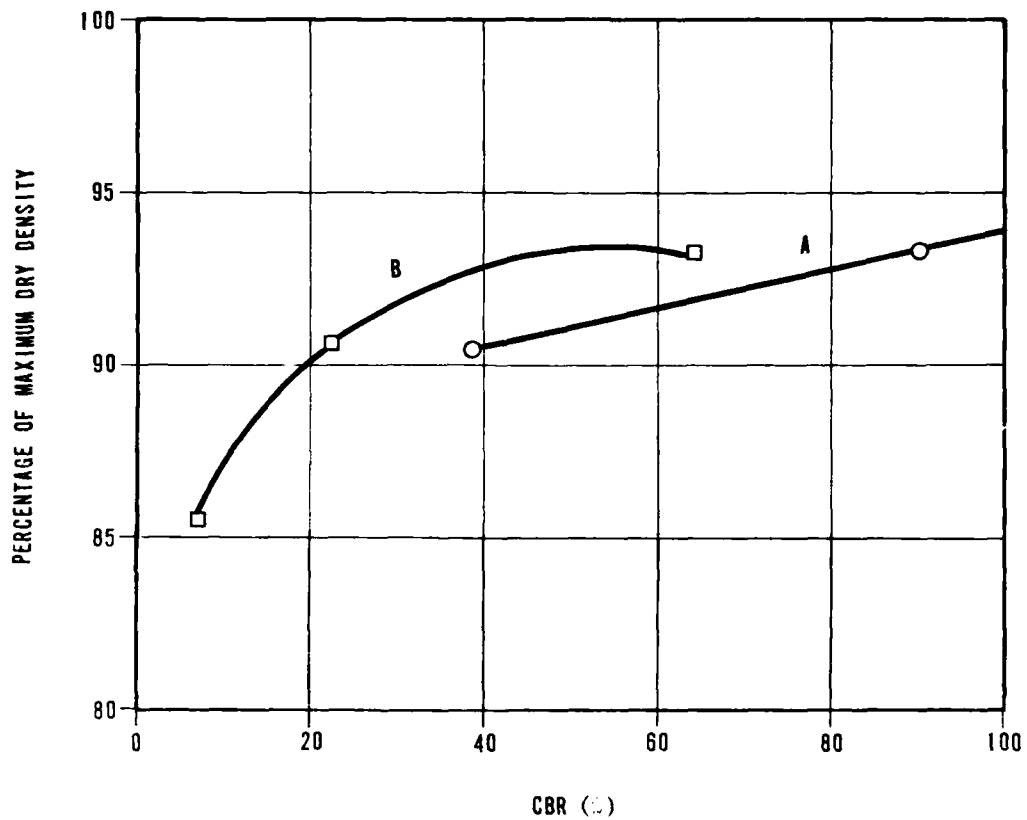
FUGRO NATIONAL, INC.

FUGRO NATIONAL, INC.

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSQ

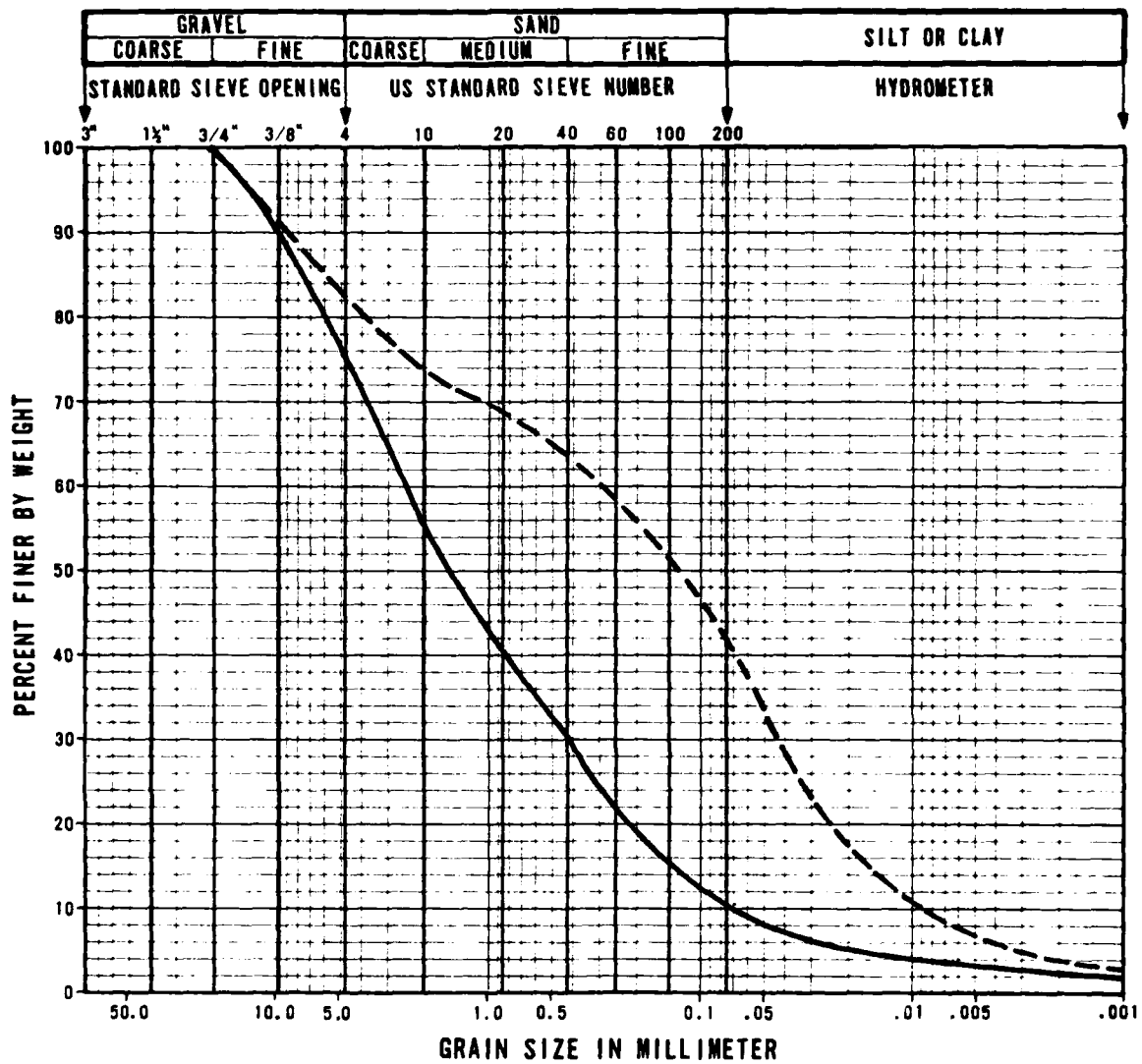
**TABLE
B-5**

FUGRO NATIONAL, INC.



SYMBOL	COMPOSITE SAMPLE NUMBER	SOIL TYPE
○	A	SP-SM
□	B	SC

<p align="center">CALIFORNIA BEARING RATIO (CBR) CURVES</p> <p align="center">RANEGRAS PLAIN, ARIZONA, SONORAN CSP</p>	
<p align="center">MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE SAMSO</p>	<p align="center">FIGURE B-7</p>
<p align="center">FUGRO NATIONAL, INC.</p>	



SYMBOL	COMPOSITE SAMPLE NUMBER	ACTIVITY NUMBER	SAMPLE INTERVAL		SOIL TYPE
			FEET	METERS	
—	A	RP-T-1	0.0 - 1.0	0.0 - 0.31	SP-SM
		RP-T-9	9.0 - 11.0	2.74 - 3.35	
---	B	RP-T-9	0.0 - 1.0	0.0 - 0.31	SC
		RP-B-16	0.0 - 3.0	0.0 - 0.91	

GRAIN SIZE CURVES, CBR TESTS
RANEGRAS PLAIN, ARIZONA
SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS

FIGURE
B-8

FUGRO NATIONAL, INC.

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAWSO

**TABLE
B-6**

FUGRO NATIONAL, INC.

APPENDIX C

GEOTECHNICAL DATA - MOJAVE SITE

TABLE OF CONTENTS
APPENDIX C

BORING AND TRENCH LOGS

LOG OF BORING MJ-B-12	Figure C-1
LOG OF BORING MJ-B-15	Figure C-2
LOG OF BORING MJ-B-17	Figure C-3
LOG OF TRENCH MJ-T-2	Figure C-4
LOG OF TRENCH MJ-T-5	Figure C-5
LOG OF TRENCH MJ-T-10	Figure C-6

SUMMARY OF LABORATORY TEST RESULTS

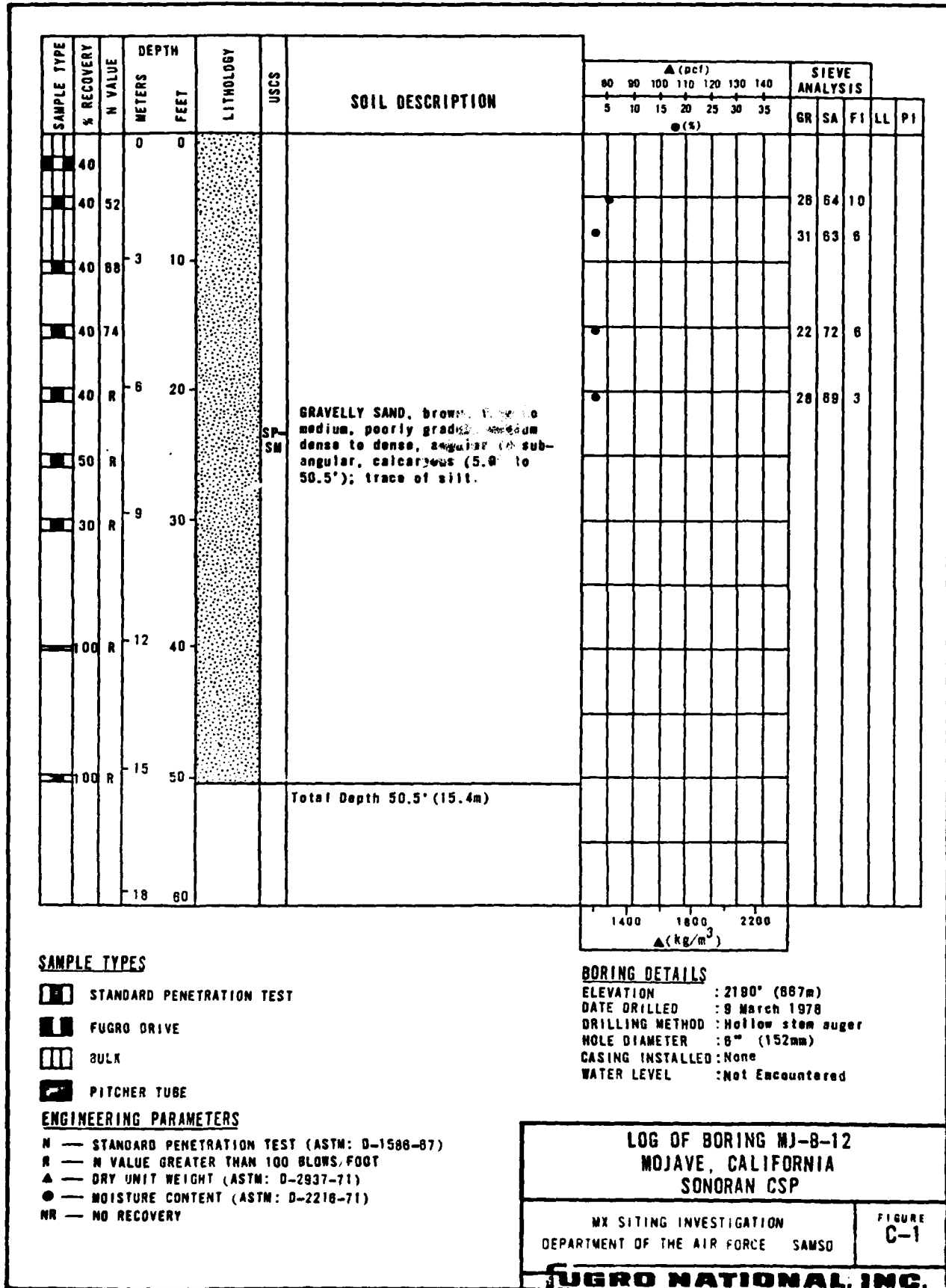
BORING MJ-B-15	Table C-1
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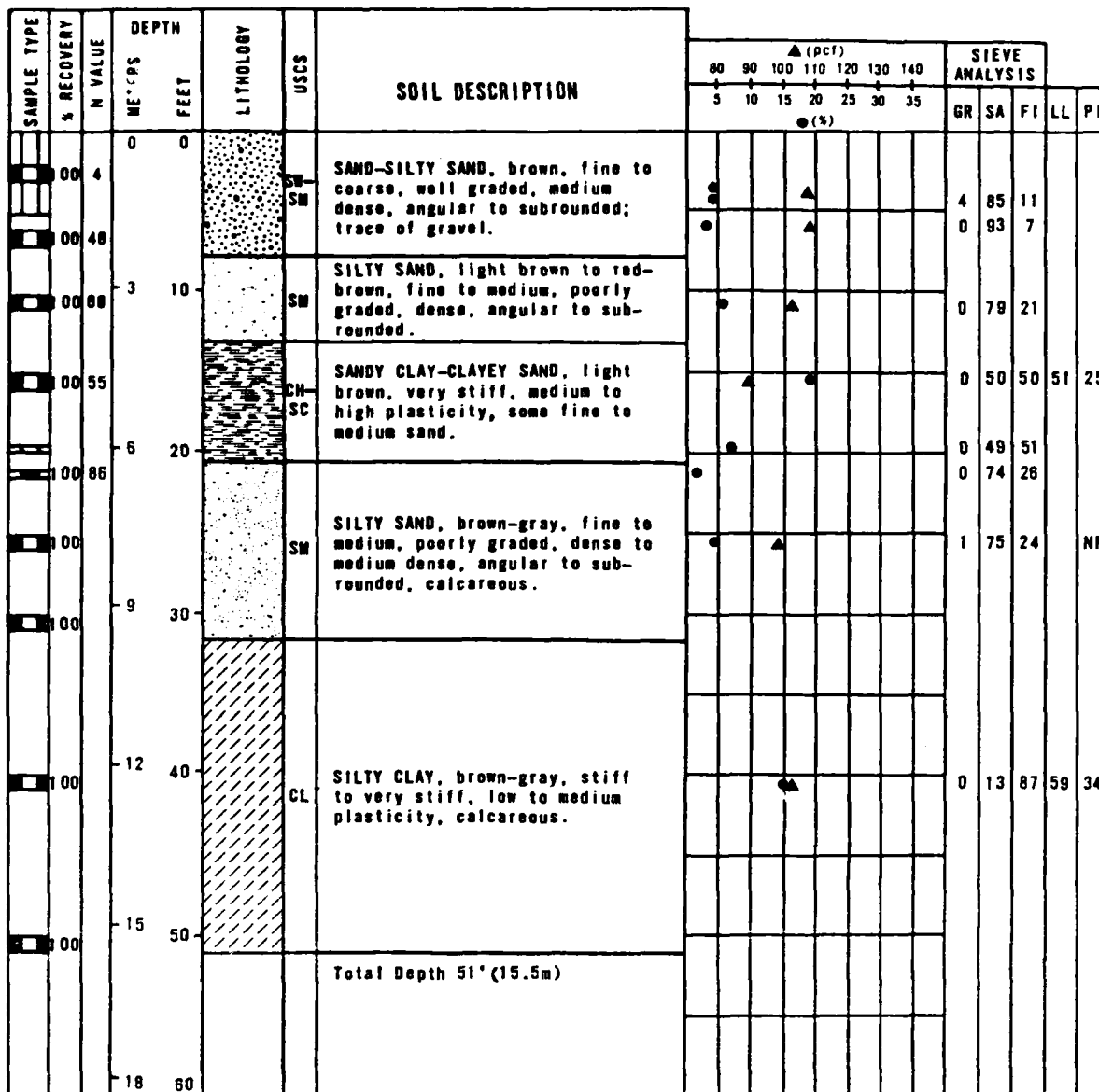
SUMMARY OF SHEAR STRENGTH TESTS

UNCONFINED COMPRESSION TEST RESULTS	Table C-2
DIRECT SHEAR TEST RESULTS	Table C-3

SUMMARY OF CALIFORNIA BEARING RATIO (CBR) TESTS

CALIFORNIA BEARING RATIO (CBR) TEST RESULTS	Table C-4
CALIFORNIA BEARING RATIO (CBR) CURVES	Figure C-7
GRAIN SIZE CURVES, CBR TESTS	Figure C-8





SAMPLE TYPES

- STANDARD PENETRATION TEST
- FUGRO DRIVE
- BULK
- PITCHER TUBE

ENGINEERING PARAMETERS

- N — STANDARD PENETRATION TEST (ASTM: D-1586-87)
- R — N VALUE GREATER THAN 100 BLOWS/FOOT
- ▲ — DRY UNIT WEIGHT (ASTM: D-2937-71)
- — MOISTURE CONTENT (ASTM: D-2216-71)
- NR — NO RECOVERY

BORING DETAILS

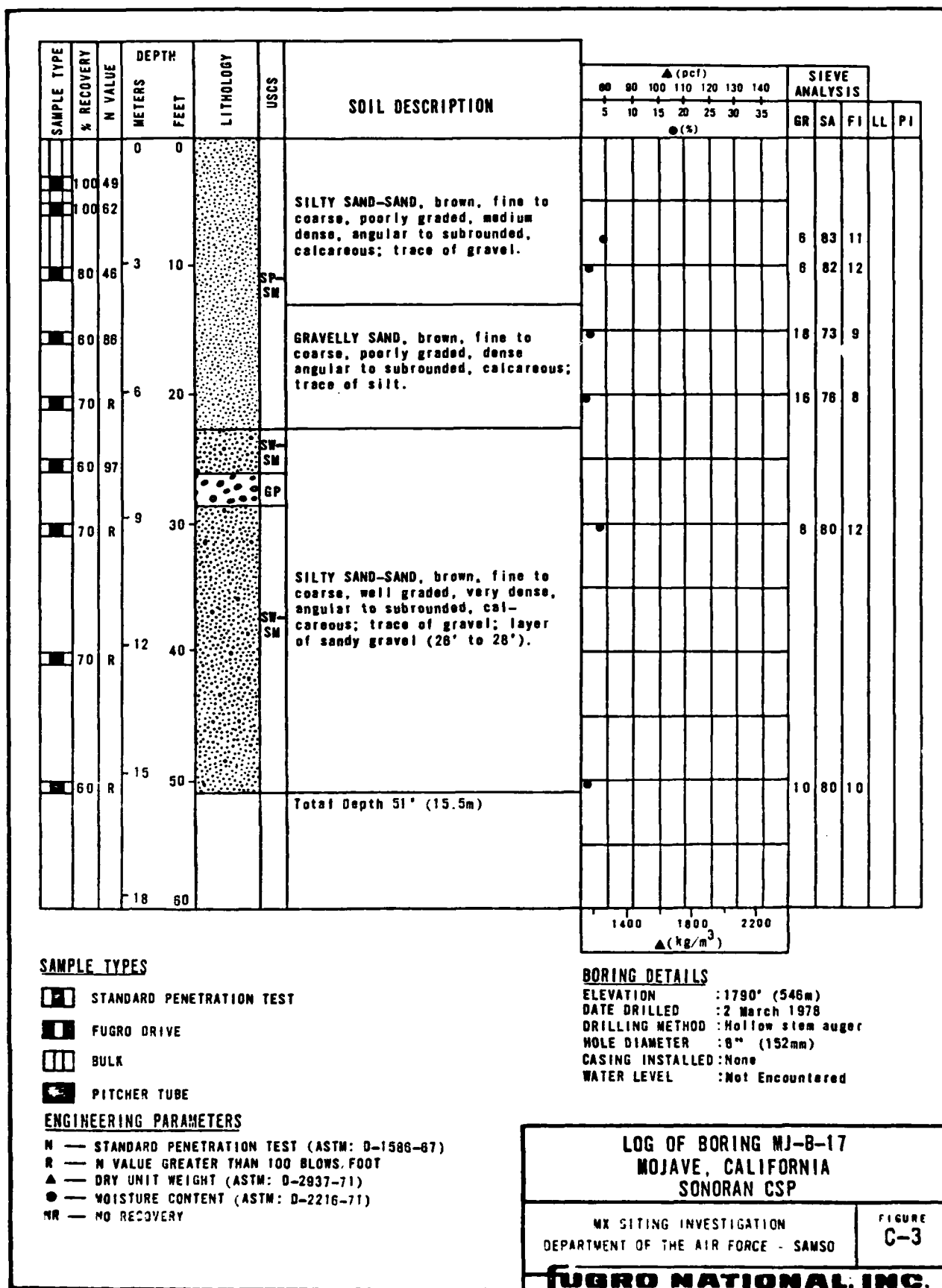
ELEVATION : 1785' (538m)
 DATE DRILLED : 1 March 1978
 DRILLING METHOD : Hollow stem auger
 HOLE DIAMETER : 6" (152mm)
 CASING INSTALLED: None
 WATER LEVEL : Not Encountered

LOG OF BORING MJ-B-15
MOJAVE, CALIFORNIA
SONORAN CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE SAMSQ

FIGURE
C-2

FUGRO NATIONAL, INC.



LOGGED BY _____ CHECKED BY _____ APPROVED BY _____

BULK SAMPLE	DEPTH METERS FEET	LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS				
						GR	SA	FI	LL	PI
	0									
	2					18	71	13		
	4									
	6		SM	Medium dense	GRAVELLY SAND, red-brown, fine to coarse, poorly graded, subrounded, calcareous; little gravel.					
	8									
	10									
	12									
	14		ML	Stiff	SANDY SILT, light brown, low plasticity, calcareous.	2	40	58	24	2
	16				Total Depth 14.5' (4.4m)					
	18									
	20									
	22									

TRENCH DETAILS

SURFACE ELEVATION : 1310' (398m)
 DATE EXCAVATED : 20 February 1978
 SURFACE GEOLOGIC UNIT : A5y
 TRENCH LENGTH : 30' (9.1m)
 TRENCH ORIENTATION : N22W

**LOG OF TRENCH MJ-T-2
 MOJAVE, CALIFORNIA
 SONORAN CSP**

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE - SANSO

FIGURE
C-4

FUGRO NATIONAL, INC.

BULK SAMPLE	DEPTH		LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS														
	METERS	FEET					GR	SA	FI	LL	PI										
	0	0		SP	Medium dense	SAND, light brown, fine to coarse, poorly graded, subrounded, calcareous; trace of silt; little gravel.	16	81	3												
	2																				
	4																				
	6																				
	8																				
	10																				
	12																				
	14																				
	16																				
	18																				
	20																				
	22																				
	Total Depth 14.9' (4.5m)																				

TRENCH DETAILS	
SURFACE ELEVATION	: 1145' (349m)
DATE EXCAVATED	: 25 February 1978
SURFACE GEOLOGIC UNIT	: A1
TRENCH LENGTH	: 37' (11.3m)
TRENCH ORIENTATION	: N80E

LOG OF TRENCH MJ-T-5 MOJAVE, CALIFORNIA SONDRAN CSP	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - SANSO	FIGURE C-5
FUGRO NATIONAL, INC.	

LOGGED BY _____
 CHECKED BY _____
 APPROVED BY _____

LOGGED BY _____ CHECKED BY _____ APPROVED BY _____

BULK SAMPLE	DEPTH METERS FEET	LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS				
						GR	SA	FI	LL	PI
	0			Medium dense						
	2					10	78	11		
	4									
	6		SP-SM	Dense	SILTY SAND, light brown, fine to coarse, poorly graded, subrounded, calcareous; trace of gravel; weakly cemented (2' to 12.5').					
	8									
	10									
	12									
	14				Total Depth 12.5' (3.8m)					
	16									
	18									
	20									
	22									

TRENCH DETAILS

SURFACE ELEVATION : 1880' (573m)
 DATE EXCAVATED : 24 February 1978
 SURFACE GEOLOGIC UNIT : A5i
 TRENCH LENGTH : 45' (13.7m)
 TRENCH ORIENTATION : N44W

**LOG OF TRENCH MJ-T-10
 MOJAVE, CALIFORNIA
 SONORAN CSP**

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE SAMS0

FIGURE
C-6

FUGRO NATIONAL, INC.

NOTES:

- (a) Sample types
 SS - Standard split spoon
 P - Pitcher
 D - Fugro Drive
 B - Bulk
 (b) NP - Not Plastic
- (c) USCS - Unified Soil Classification System
 (d) * Indicates that test has been performed and results are included in this report.

WEIGHT						ATTERBERG LIMITS (b)			USCS (c)	IN-SITU					COMPACTED			SPECIFIC GRAVITY OF SOLIDS	TRIAxIAL (d)	UNCONFINED COMPRESSION	DIRECT
STANDARD SIEVE NO				PARTICLE SIZE (mm)						DRY UNIT WEIGHT		MOISTURE CONTENT (%)	SATURATION (%)	VOID RATIO	MAXIMUM DRY DENSITY		OPTIMUM MOISTURE (%)				
SAND			SILT OR CLAY							(pcf)	(kg/m ³)				(pcf)	(kg. m ³)					
10	40	100	200	.005	.001	LL	PL	PI													
83	16	17	11	4	2				SW-SM			4.3									
									SP-SM	107.2	1717	4.4	20.8	0.60							
84	16	14	7	1	1				SW-SM	108.1	1732	3.2	15.2	0.60							
91	44	24	21	12	11				SM	103.3	1655	6.0	25.6	0.63						*	
100	75	55	50	11	7	51	26	25	SC-CH	88.7	1421	19.0	57.1	0.90						*	
98	76	61	51	22	15				CL			7.4					2.63				
98	72	39	26	6	3				SM			2.1									
96	55	59	24	8	7			NP	SM	97.5	1562	4.0	15.0	0.73						*	
100	60	91	87	34	23	59	25	34	CH	104.4	1672	15.2	62.0	0.61						*	

2

SUMMARY OF
 BI
 MOJAVE, CA

MX SITING I
 DEPARTMENT OF THE

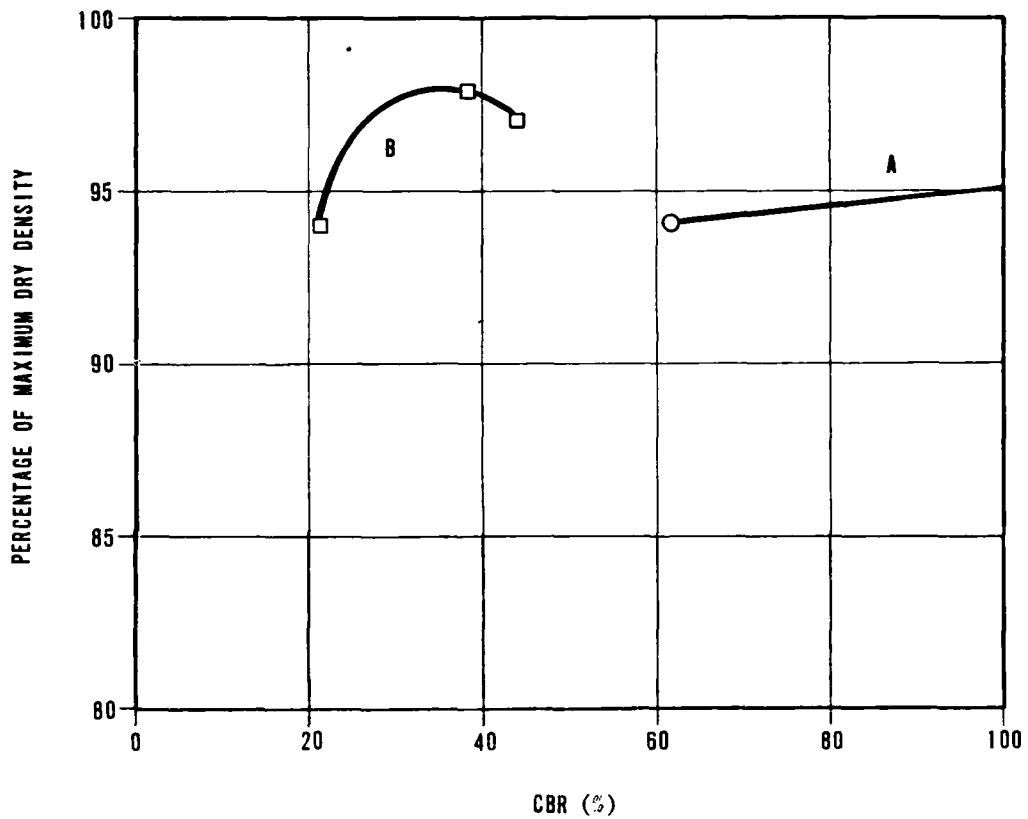
FUGRO

SUMMARY OF LABORATORY TEST RESULTS	
BORING MJ-8-15	
MOJAVE, CALIFORNIA, SONORAN CSP	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE SAMS0	TABLE C-1
FUGRO NATIONAL INC.	

FUGRO NATIONAL, INC.

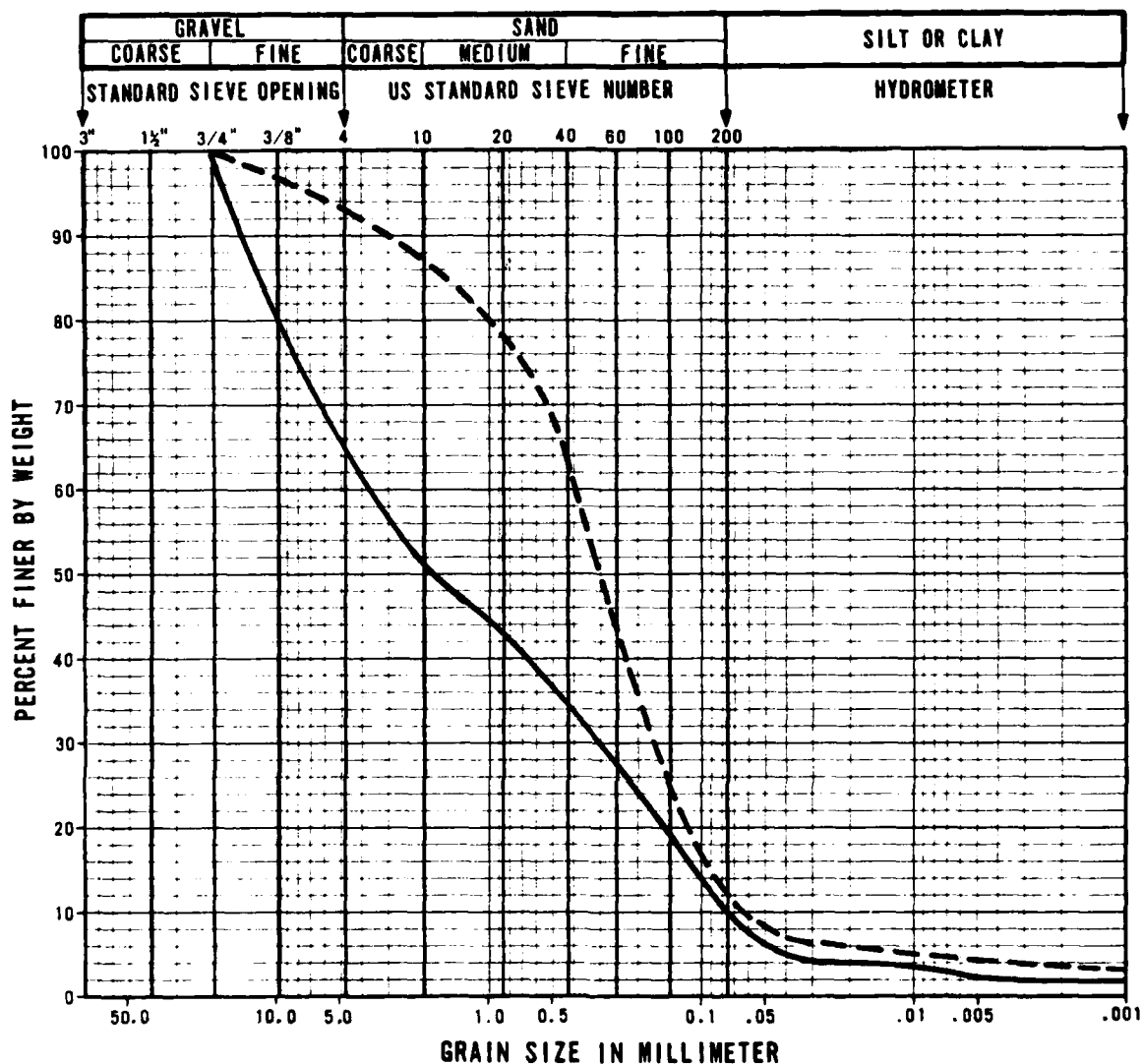
FUGRO NATIONAL, INC.

FUGRO NATIONAL, INC.



SYMBOL	COMPOSITE SAMPLE NUMBER	SOIL TYPE
○	A	SP-SM
□	B	SP-SM

<p align="center">CALIFORNIA BEARING RATIO (CBR) CURVES</p> <p align="center">MOJAVE, CALIFORNIA, SONORAN CSP</p>	
<p align="center">MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE SAMSO</p>	<p align="center">FIGURE C-7</p>
<p align="center">UGRO NATIONAL, INC.</p>	



SYMBOL	COMPOSITE SAMPLE NUMBER	TRENCH NUMBER	SAMPLE INTERVAL		SOIL TYPE
			FEET	METERS	
—	A	MJ-T-1	1.0 - 3.0	0.31 - 0.91	SP-SM
		MJ-T-3	1.0 - 3.0	0.31 - 0.91	
--	B	MJ-T-4	1.0 - 3.0	0.31 - 0.91	SP-SM
		MJ-T-10	1.0 - 4.0	0.31 - 1.22	

GRAIN SIZE CURVES, CBR TESTS
MOJAVE, CALIFORNIA
SONORAN CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

FIGURE
C-8

FUGRO NATIONAL, INC.

DATE
LME
-8